Government Involvement in the Innovation Process

A Contractor Report to the Office of Technology Assessment

Office of Technology Assessment

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A Contractor's Report to the Office of Technology Assessment

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Office of Technology Assessment

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FOREWORD

As part of its planned comprehensive assessment of national R&D programs and priorities, the Office of Technology Assessment is studying policy tools to encourage innovation. This document, *Government Involvement in the Innovation Process*, is an interim report from this study.

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PREFACE

This report was prepared by the Center for Policy Alternatives at the Massachusetts Institute of Technology, under a contract awarded by OTA. It was undertaken to acquaint OTA with Government policies that relate to or bear upon technological innovation—the process that leads to the commercial introduction of a new technology.

The study included an examination of the major factors that currently influence the process of introducing new goods and services to the user. These factors include the following: incentives and funding for basic research; tax, patent, procurement, and antitrust policies; regulations; size, sector, and locale of the business; subsidies; inflation rate; available technical, marketing, and management skills; credit; and the formation of capital (see pp. 23-25).

The report also identifies and describes the activities of five other industrialized nations in the support of science and technology (see pp. 43-47). The applicability and transferability of these approaches to the United States are questionable.

The report is summarized in chapter I, where the contractor's findings are translated into suggestions and options. The authors identify 10 opportunities for Congress to consider for facilitating beneficial innovation. These complex issues deserve much greater consideration than was possible in the brief study. However, it illustrates the complicated dynamics of the innovation process.

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A Contractor's Report to the Office of Technology Assessment

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The research underlying this report was supported by a contract from the Office of Technology Assessment, U.S. Congress, to the Center for Policy Alternatives at the Massachusetts Institute of Technology.

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Chapter I

SUMMARY

INTRODUCTION

This report is concerned with the relationship between Government action and technological innovation in the civilian sector of the U.S. economy. Its principal objective is to develop some of the key policy issues important in designing future programs affecting innovation. These issues are concerned with promoting technological innovation for economic purposes, using innovation to achieve a variety of social goals, and controlling the adverse consequences of new technology. The issues have been derived from several research components: consideration of the appropriate role of Government in the technological innovation process (chapter II); a knowledge of the range of current U.S. Government actions bearing on innovation and an understanding of the innovation process and how industry responds to such Government interventions (chapter III); and an acquaintance with the experience of comparable industrialized nations in fostering technological innovation (chapter IV). The result of the analysis is not to prescribe specific legislative actions for Congress, but to suggest broad areas where Congress might consider programs in the future to reinforce the momentum or influence the direction of U.S. technological development.

THE GOVERNMENT ROLE IN THE INNOVATION PROCESS

Governments in all modern industrialized countries employ a variety of techniques to promote and shape technological development. Each has concluded that the free action of the market is not sufficient to achieve the desired long-term goals of technological strength and independence. For many different reasons, governments may choose to intervene where market forces are clearly incapable of achieving defined national objectives.

First, with respect to knowledge generated from the research and development process, private economic units cannot capture all the benefits arising from the creation of new knowledge and will tend to invest in those projects whose results they can control. Similarly, in some cases, like public health, few economic units benefit from research investments. Hence, from the societal point of view, underinvestment in important research areas may occur because of the nonappropriable or public nature of knowledge.

Second, while some larger companies in the United States may invest vast amounts of resources in research and development, the limited scale of most private economic units prohibits their undertaking very large-scale research. Hence, Government performance or support of some kinds of R&D as well as many forms of basic research is necessary.

Third, the public interest often requires a Government role to shape and control the social and political nature of new technological development. The private sector, responding to market signals other than social priorities, cannot be expected to ensure the welfare of society and the Nation. This situation may require regulation to correct market failures (for example, pollution control) or substitution of social decisions for the market allocation of resources (for example, transportation facilities for the elderly and the handicapped).

U.S. EXPERIENCE

The task of documenting the current content and effect of U.S. Government policy toward innovation has been approached from two perspectives. Part of the analysis concentrated on identifying and categorizing existing Government programs. A parallel effort attempted to illustrate some of the effects of Government programs in selected industries. The utilization of these two perspectives is based on an important premise of this report—that a full understanding of the Government-innovation relationship involves not only a knowledge of existing programs but also of the industrial contexts in which their impacts occur.

Government Programs

The number and variety of Government programs affecting innovation is very large, although many, if not most, are not necessarily designed with that goal in mind. On the contrary, they are directed toward goals as disparate as economic growth, job security, and environmental quality. It is useful and necessary for conceptual purposes to establish a framework for organizing these actions into a number of self-contained program areas which reflect the major technology-related themes of current Government policy. Such a framework can (1) provide a convenient analytical framework for viewing the programs, (2) illustrate the programs' relationships to technological innovation, and (3) furnish a common structure within which proponents of different viewpoints can make a case for reorientation of national policy regarding technology.

The framework developed for this report is shown in table 1.

For each area, the existing programs have been identified and categorized. This is done through the use of 13 matrices (see pp. 23-25), whose headings illustrate some aspects of the relationship of the programs to innovation. This categorization was useful to the research effort in that it highlighted areas of current program emphasis and neglect. Conclusions of this nature, reached from the matrices, were used as a major source of input to the development of the key policy issues presented in chapter V.

Table 1.—Thirteen Program Areas

Area	Program
I.	The assessment of new and existing specific technologies.
II.	Direct regulation of the research or development of new products and processes.
III.	Direct regulation of the production, marketing, and use of new or existing products.
IV.	Programs to encourage the development and utilization of technology in and for the private goods and services sector.
V.	Government support of technology for public services where consumers are the primary users.
VI.	Support for the development of technology where the Federal Government is the primary user.
VII.	Support for the science base necessary for the development of new technology.
VIII.	Policies to affect industry structure that may affect the development of technology.
IX.	Policies affecting supply and demand of manpower resources having an impact on technological change.
X.	Economic policies with unintended or indirect effects on technological innovation.
XI.	Policies affecting international trade and investment.
XII.	Policies intended to create shifts in consumer demand.
XIII.	Government policies responding to worker demand having impact on technological change.

A Comparison of Selected Industry Experiences

The experience in several industries has been reviewed to determine the nature of the impact of Government actions on the innovation process. From this sample of industries, three policy instruments emerge as the most effective Government policies in influencing the rate and direction of technological change:

- Regulation (pollution, health and safety, energy conservation);
- Federal R&D support (direct to industry, indirect, and Government-performed); and
- Procurement of innovative technology-based products.

In general, these industry studies have shown that several characteristics of Government actions have made them particularly effective in promoting technological innovation. First, Government programs and incentives that help new firms and ventures get started normally have resulted in important innovative activities in various sectors. Second, where the Government has provided a market for new technologies or has given direct R&D support, firms have frequently responded by changes in products and processes as a result.

Third, actions that complement normal competitive pressures for change in an industry have been effective in inducing technological change, largely because they have taken into account the force of the market on innovations. For example, regulations with respect to energy conservation have reinforced normal market forces to stimulate new fuel conservation innovation.

Fourth, while Government performance of basic research has made many outstanding contributions to industrial innovation, evidence shows that Government development *per se* of new products and processes has often been overtaken by the rapid pace of innovation in private industry where superior knowledge of the production process and product design prevails. This observation leads to the conclusion that Government action of this nature is most effective where it complements normal market forces operating within the private sector.

KEY FEATURES OF GOVERNMENT SUPPORT FOR TECHNOLOGICAL INNOVATION IN SELECTED FOREIGN COUNTRIES

While there exists no clear equivalent to the U.S. experience among foreign countries, the success and failure of government involvement in the innovation process abroad can be instructive to U.S. policymakers. In analyzing the major features of programs in Japan, the United Kingdom, West Germany, and France, several clear contrasts in philosophies and tactics with respect to encouraging technological change are apparent. In particular, the relative success of certain Japanese approaches and the lack thereof of several British programs may offer interesting lessons for future U.S. programs. On the whole, however, several common elements tend to emerge in observing the approaches of these four case countries, namely:

- *Direct government support for product development and R&D in private firms* tends to be a prominent instrument in stimulating innovation abroad.
- *Government support for technological developments basic to a wide range of industry* is almost ubiquitous (e.g., friction research).
- *Use of government procurement* is relied on to strengthen demand for innovative technologies and reduce market risk and uncertainty for firms.
- *Provision of capital* by the government to firms seeking to introduce innovative products and/or processes is present in all these countries, although the form and timing differs from case to case.
- Emphasis on *changes in industrial structure* is apparent in all four countries in order to meet the requirements of technological progress and international competition.
- *Emphasis on export performance* in international markets is a clear priority in all these countries, and is translated into several types of incentives for new products and processes.
- *Emphasis on labor training and manpower development policies* constitutes a major feature in the technology development policies of these countries.

ISSUES IN FUTURE U.S. GOVERNMENT POLICY TOWARD TECHNOLOGICAL INNOVATION

On the basis of what is known about current U.S. policy toward technological innovation, industry's response to these programs, and the insights gained from foreign experience, several policy issues have emerged which, in the author's opinion, merit consideration by Congress. The following summarizes these issues and some illustrative, although far from exhaustive, initiatives which may derive from them.

ISSUE 1

Direct Support of Nonmission-Oriented Technology

Currently, the U.S. Government provides no direct support for nonmission-oriented technological development, unlike other industrialized countries where this support is frequently prominent. There are several reasons for considering such support. First, the United States is facing growing competition in international markets in technology-based products from countries where Government support for such technologies is strong. Second, the social returns on technological innovation are frequently greater than those accruing to the individual inventor and may take the form of increased employment, environmental protection, and product safety. Therefore, there are many areas in which the private sector will underinvest in the development of new technologies because of the inability of the developer to appropriate the rewards. Congressional initiatives for the implementation of a policy to support the development of such technology might include:

1. Legislation directing the procurement of innovative products at a price that provides for an indirect subsidy of R&D costs;
2. Support for a program of advanced research responsive to a variety of social goals, but not appropriable by any single firm; and
3. The granting of exclusive patent rights to individuals and firms making inventions on federally supported R&D programs.

ISSUE 2

Reconsideration of the Role of the National Laboratories

Most of the existing National Laboratories were set up to support a specific governmental mission such as nuclear weapons development or space research. In many instances, however, these laboratories have expanded their roles beyond the original missions. In other cases, the changing nature of Government policies has brought on changes in their activities. At present, many of the National Labs compete directly with private industry in performing research directed at the development of civilian technology of commercial significance. Options available to Congress to better utilize the National Laboratories include:

1. The definition of explicit missions, as well as the identification of, and justification for, new research roles for them; and
2. Development of guidelines for use by the funding agencies in deciding which projects to fund in-house and which to support in the private sector.

ISSUE 3

Facilitating New Entrants Into the Market

New and small firms have been shown to be leading innovators in many areas, largely because they are often formed on the basis of a new idea or product and have great flexibility in introducing radically new products into the market. Such firms frequently face a variety of barriers in establishing or expanding their operations, including restrictions on venture capital, tax disadvantages (including less favorable than before capital-gains taxation), regulatory barriers, and market dominance by larger, established firms. Congress might usefully consider several options to ease the process of entering the market for new firms and individual entrepreneurs, such as:

1. Selective use of Government procurement policy;
2. Stricter enforcement of antitrust laws;
3. Assistance to new firms in meeting regulatory requirements; and
4. Greater patent protection for the small innovator.

ISSUE 4

Diffusion of Technology Within the Private Sector

Better diffusion of existing technologies and existing technical information would serve to stimulate innovation in several ways. First, the productivity levels of industries could be raised by closing technology gaps. Second, by helping small- and medium-size firms compete with larger ones, new innovative products and processes could be encouraged. Third, compliance with regulation could be facilitated by diffusing knowledge of the means to comply. Finally, new uses of technologies could be promoted by transfers among different types of industries. Existing market structures tend to inhibit wide application of technologies, thereby giving undue advantages to large technology leaders. Several instruments are available to the U.S. Government to overcome such market rigidity, some of which might be:

1. Establishment of a network of local technical centers;
2. Support for industrial cooperative activities by small firms;
3. Support for technology information/communications systems;
4. Compulsory licensing of technologies to competitors when leading firms reach a certain market share; and
5. Government purchases of technology for resale to new users.

ISSUE 5

Implementation of Environmental and Safety Regulations

The effect of regulation on technological innovations remains highly controversial. The research which has been undertaken in this area indicates that the effects which exist, though substantial, cannot be simply characterized. At a minimum, it is necessary to recognize both positive and negative impacts and to distinguish the effects of regulation on the development of new compliance technology from the more general effects that it may have on the rate and direction of technological innovation in the broad sense. Insufficient attention has been given to new means of implementing regulatory legislation so as to encourage innovative compliance technologies that help to achieve regulatory goals. For example, the following regulatory mechanisms, among others, deserve consideration in the U.S. context:

1. Strict liability for pollution damage;
2. Effluent taxes;
3. Joint R&D for pollution control; and
4. Government support for the development of compliance technology.

Evaluation of the means to promote innovation in regulatory compliance is needed as well as immediate application in selected contexts of new policies to facilitate the achievement of regulatory goals via technological change.

ISSUE 6

Manpower Resources, the Labor Market, and Technology

An infrastructure element essential to technological change is qualified manpower. The rapidly changing nature of technology requires a flexible and farsighted manpower policy to prepare for future technological development, both in terms of training for the future and helping workers adjust to the dislocations that are frequently caused by technological change. A comprehensive manpower policy adopted by Congress might include several important components to satisfy these needs, such as:

1. An analytical capacity within Government to conduct continuing forecasts of future skill requirements in different sectors;
2. An effective program of labor adjustment assistance to facilitate the adaptation of workers and their skills to new job requirements; and
3. A long-term strategy for scientific and technical education and training adapted to future manpower needs and technological trends, particularly in the area of engineering education.

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ISSUE 7

International Commerce and Domestic Innovation

Technological innovations are vital to U.S. industries in competing with foreign producers in both international and U.S. markets. Government efforts are needed to help U.S. industries enhance their competitiveness by promoting domestic innovations as well as facilitating the adaptation and improvement of advanced foreign technologies. For industries that are noncompetitive in the long run, Government measures are needed to assist labor and business adjust structurally and to soften dislocations during the transition.

ISSUE 8

Support for Sector-Specific Microanalysis

The relationship between Government action and technological innovation varies significantly among different industrial sectors. Because there is a lack of good studies of specific industries and the effects of Government programs on them, Government policymaking in various areas is often severely hampered. No sector-specific microanalytical capability of significant size exists in Government today. Consideration should be given to support for such a capability to aid decisionmaking in areas ranging from regulation to tax policy. This capability need not necessarily be lodged in the Government, but could also successfully be established with Government support in universities or other parts of the private sector.

ISSUE 9

Support for Hazard Analysis

Because hazards too often go unrecognized until their dangers reach crisis proportion, it is important to create a capability to anticipate them, or at a minimum, to institutionalize a means to monitor their presence. Although various agency programs attempt to assess and prevent hazards, the existing efforts are deficient in several respects. Hazard analysis as currently performed in Government lacks coordination and is not contained within the explicit mission of many agencies. Consequently, it is an underdeveloped discipline. Several policies deserve consideration, including:

1. A centralized agency to strengthen the U.S. hazard analysis capability;
2. Government support for development of this discipline in universities, worker, and consumer education; or
3. A hazard analysis requirement for industrial firms.

ISSUE 10

Affecting the Demand for New Technologies

Perhaps as a result of the overemphasis on R&D as a component of the innovation process, Government policy to date has tended to focus more on the supply of new technologies than the demand. However, policies that work through influences on demand have often been shown to be more effective in eliciting innovative products and processes. Government procurement is one notably successful example, and environmental regulation may sometimes work in a similar fashion to change demand. New demand-oriented policies should be considered, including mechanisms that create new or expanded markets, for certain kinds of technologies, e.g., procurement, user subsidies, regulations; and mechanisms that directly influence consumer demand, e.g., information provision or advertising regulation.

Chapter II

GOVERNMENT INVOLVEMENT IN THE INNOVATION PROCESS

Policy Implications

GOVERNMENT INVOLVEMENT IN THE INNOVATION PROCESS

Policy Implications

INTRODUCTION

This report is concerned with the relationship between Government action and technological innovation in the civilian sector of the economy. Because that relationship is exceptionally wide-ranging and complex and its importance is subject to considerable debate, the general effectiveness of Government influence on innovation cannot be adequately assessed in this work, nor can a thorough evaluation of individual programs be provided. Neither task is the purpose here. Rather, this document is intended to accomplish the following:

- To develop an appropriate framework for viewing the relationship between Government action and innovation.
- To provide a comprehensive overview of the major existing U.S. Government programs and policies having both intended and unintended effects on innovation.
- To understand typical responses of U.S. industry to Government programs in several selected industry contexts.
- To review some selected experiences of foreign governments in the innovation process, taking note of particularly effective or ineffective policies.
- To suggest a series of important issues concerning the Government-innovation relationship in the United States to provide a basis for considering the reorientation of existing policies.

It is important to be clear at the outset about both the definition of innovation and the range of Government programs with which this report is concerned. Innovation is the *commercial* introduction of a new technology and is not to be confused with invention, which is the development of a new technical idea. The innovation process includes a complex and interconnected set of activities leading from invention to commercial introduction, but not necessarily in any prescribed sequence. Although R&D is often an important part of this process, it is by no means always the most important, nor is it often likely to be a sufficient condition for successful innovation.

The interaction between Government programs and innovation is very wide-ranging, and Government influence on all elements of the innovation process may be significant. This report is concerned with all aspects of that influence. Thus, the Government programs surveyed include those intended to enhance innovation as well as those intended to control it. They include not only those programs directed at the actual commercial introduction of a new technology, but also those affecting the various factors and inputs leading to innovation and the various social impacts resulting from innovation. In addition, the unintended but nevertheless important effects of programs designed to serve a variety of social purposes not directly related to technological innovation are also considered.

The Approach and Structure of This Report

There were several elements to the research involved in this report. This chapter explores the various justifications for Government concern with innovation. In chapter III, the U.S. experience was considered from two perspectives.

One element began with a comprehensive documentation of existing Government programs and drew upon a series of analytical studies,[1] which attempt to understand their effects (*Government Programs,* p. 19). Although this approach was useful, it was not sufficient to understand fully the complexity of the Government-innovation relationship. Because the focus of this approach was on programs and their intended purposes, it was unable to uncover some of the unintended consequences of the program or assess programs fully in combination.

In order to have a more balanced approach, a second element of the research focused on several industries where the total effects of Government programs were felt (*A Comparison of Selected Industry Experience,* p. 35). Studies utilized here attempted to understand the nature of the innovation process in industry[2] and whether and how Government action has actually influenced the pattern of innovation in an industry—within the context of other forces that also influence it. The combination of these two research elements yielded a relatively full factual picture of the Government-innovation relationship. Both perspectives were necessary to obtain this understanding.

Another major element of the research drew upon a series of studies[3] examining foreign government policies in regard to technological innovation (chapter IV). This analysis provided useful contrasts to the U.S. experience. None of these research efforts involved original empirical research; rather, each was a synthesis of existing studies.

The final element of this research involved utilizing all of these components in order to derive a series of important policy issues for congressional consideration (chapter V). It should be noted that these issues do not attempt to recommend specific legislative actions, but rather to suggest broad areas where Congress might consider future actions to reinforce the momentum or channel the direction of U.S. technological development.

These components of the analysis and the relationships among them are presented diagrammatically in figure 1.

[1]See, for example: 1) *The Impact of Governmental Restrictions on the Production and Use of Chemicals,* CPA, December 1976, 2) *An Analysis of the Effects of Public Regulation on the Copper Wire Industry,* CPA, March 1977, and 3) *Program Development Procedures and Transfer Mechanisms in the National Sea Grant Program,* CPA, November 1977. These studies focused on the overall effects of individual programs, not just the relationship to innovation. They were useful to this research effort in providing factual material about existing programs, in developing evaluative tools, and in placing the Government-innovation relationship within context of other governmental goals.

[2]These studies have been documented and summarized in other Center for Policy Alternatives reports, including an earlier report to the Office of Technology Assessment, *Government Action and the Innovation Process,* April 1977, the results of which have been incorporated into this document.

[3]See *Government Support for Technology: An Examination of the Foreign Experience,* CPA 75-12, 1975. The results of this study and others were summarized in the April 1977 CPA report to OTA (see footnote 2) and are recapitulated in chapter IV of this report.

THE GOVERNMENT ROLE IN THE INNOVATION PROCESS

Technological innovation in the civilian sector of the U.S. economy occurs largely as a direct result of the activities of private firms. This being the case, one may well ask why the U.S. Government should be concerned with innovation and what, even given this concern as a legitimate governmental function, its appropriate role should be. Various governments answer this question differently and thus the degree of involvement in industrial innovation varies from country to country, influenced in part by the prevailing economic and political systems. For example, many governments, in both developed and developing countries, own and run enterprises that would be private in the United States. This is especially true in heavy or high-technology industries, where governments often become the prime developers, users, and marketers of innovations. Even when the government does not own the producing enterprises, subsidization and or direct support for the innovation process in industry is common.

This is not to argue that the U.S. Government should necessarily do likewise. However, it should be recognized that the governmental

Figure 1.—Government Involvement in the Innovation Process
(Diagrammatic View of CPA Analysis)

Policy Questions

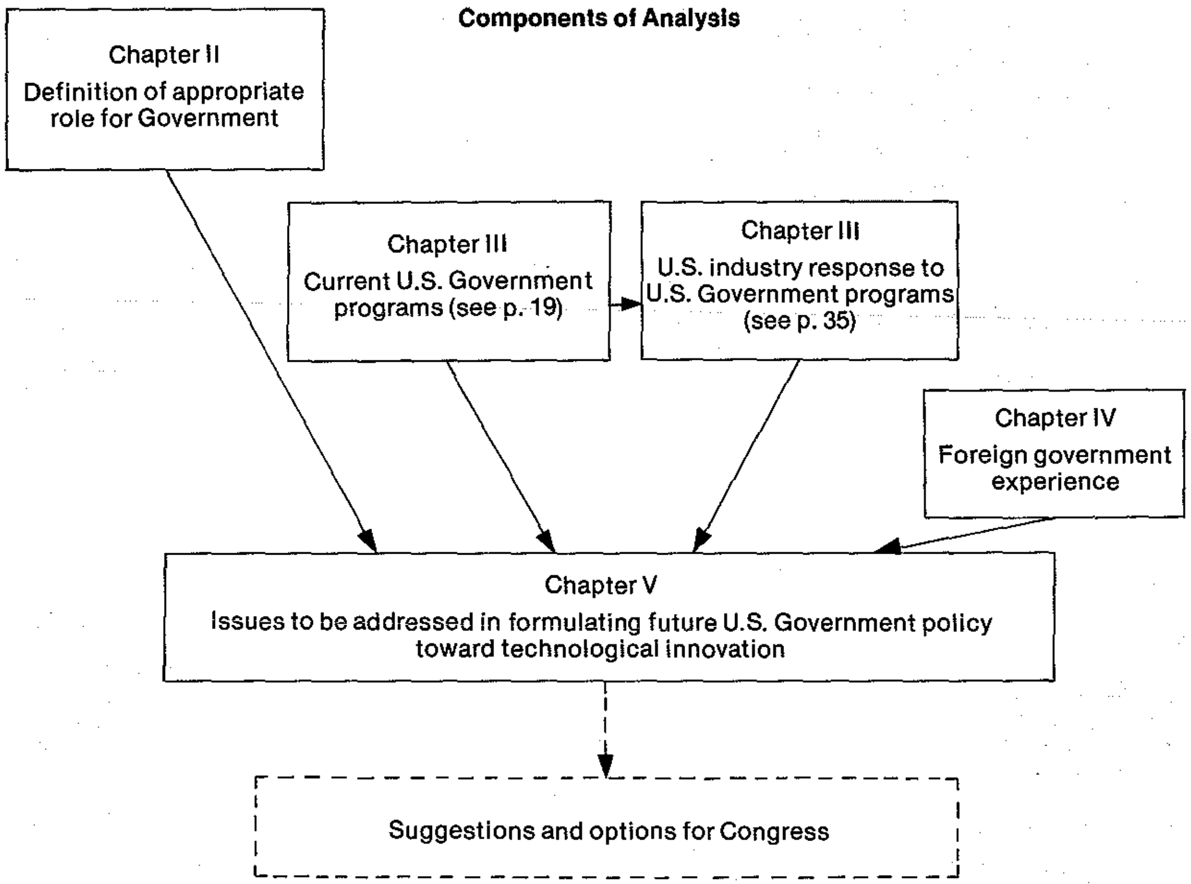
Why should Government be involved in technological innovation?

How does the U.S. Government currently act on the innovation process?

How do foreign governments affect the innovation process?

What future policies should the U.S. Government consider to influence technological innovation?

What specific legislative measures are available to Congress?



SOURCE: Center for Policy Analysis.

presence in the United States may be as significant as that in other countries, although it takes a different form. For example, the U.S. Government has historically been involved in supporting selected industries (see chapter III, *Government Programs*, pp. 19) and currently plays a major but indirect role in the innovation process through various economic and social policies or regulations. Although many of these programs and regulations are not directly aimed at influencing the innovation process, their impacts may often be greater than those arising from direct Government support for technological development.

Reasons for Government Concern With Innovation

Governments are not concerned with technological innovation for their own sake, but rather attempt to promote it or manage it because of the social, economic, and political effects that result. For example, because technological change has been shown to be an important contributing factor to economic growth, governments seek to encourage it. Similarly, innovation is promoted in order to increase productivity and retard inflation or to improve the international competitiveness of a nation's products and improve its balance-of-payments position. On the other hand, governments are also vitally concerned with the adverse effects of technological change, including unemployment, pollution, and unsafe products. In this case, policies may be directed toward the control rather than the promotion of new technologies. In none of these instances, however, is the relationship between the social goal and technology simple or unidirectional. For example, although technological changes may have led to pollution, they must also certainly occur in order to control it. The crucial point is that in a technologically based society, the process of innovation is intimately related to many, if not most, of the important social goals of that society and that innovation is therefore a critical element of most government policies.

Going beyond these rather general reasons for government concern with innovation, there are also strong arguments why the government should intervene directly to influence innovation under certain circumstances. These interventions are usually justified because of market failures or deficiencies of the following kinds:

THE PUBLIC NATURE OF KNOWLEDGE

Private firms may underinvest in the development of new technology (from a societal point of view) because they are not able to capture all of the benefits resulting from such investments. This situation, often called the "appropriability problem," occurs because the knowledge which results from investments in technical development can usually be readily acquired by others who will compete away part of the benefits from the original developer. Basic research in particular suffers from this problem because its output is usually an advance in scientific or technological knowledge that can subsequently be used in applied research and commercial development by a wide and often unforeseeable range of firms. Moreover, new technical developments also tend to be highly uncertain in terms of results and utility. Thus, direct government support of this class of R&D is necessary to correct for underinvestments. In addition, government support for technical development may have positive effects for firms other than those in which the research is performed, thus creating "positive externalities."

STRUCTURAL CHARACTERISTICS OF INDUSTRY

The problem of indivisibility exists where economies-of-scale requirements prevent small organizations from undertaking certain activities viably and efficiently. For example, certain industries may be too fragmented and firm size too small to support an adequate research and product development effort. Furthermore, large oligopolistic firms may concentrate their resources on short-term improvements in existing products rather than on risky and market-disturbing long-term innovations. Individual consumers face a similar problem in that they often lack the information to make wise purchases or the market power to be effective bargainers. In these situations, the large economies of scale suggest that support from the Federal Government is needed for some types of R&D, or that cooperative industrial or consumer efforts must occur in order to attain the minimum efficient size.

SOCIAL AND POLITICAL NEEDS

The "public goods" problem refers to the fact that there are certain goods whose benefits are difficult or impossible to deny to a citizen who is unwilling to pay for them. For example, all U.S. residents enjoy the full benefits of national defense even though they might not want them. Therefore, for public goods, the decision of how much to supply to individual units cannot be made by the market, but must be made by the political system. This is in contrast to the situation where the market can provide the appropriate results if the government attaches the right costs and benefits to the appropriate decisionmaking units. It is thus justifiable for the government to directly support the R&D for these types of goods.

There is also another direct, intended role for government. In part, this role is one of control. Technological innovations are frequently accompanied by undesirable social or economic consequences, such as environmental pollution, health or safety hazards, and displacement of workers. In these cases, the government as overseer and protector of the public interest must play a very direct role in ameliorating such undesirable effects, via planning, controls, regulations, or transfer payments. The government presence is necessary either because the private market has not eliminated or cannot be expected to eliminate these undesirable effects, or because efficient market solutions are not desirable social policy.

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Chapter III

U.S. EXPERIENCE

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Chapter III

U.S. EXPERIENCE

This chapter is concerned with documenting the status and effect of U.S. Government policy regarding technological innovation. It presents factual information about which programs exist and suggests a framework within which to consider their effects.

The task has been approached from two perspectives. One, a "program perspective," concentrates on the documentation of existing U.S. programs and policies that have an important relationship to technological innovation. These have been organized into a series of 13 major policy areas and are presented in *Government Programs,* see below. The second approach, an "industry perspective," focuses on a series of industrial sectors and considers what have been the effects of Government action on innovation in those sectors. This is presented in *A Comparison of Selected Industry Experiences,* p. 35. The presentation of two different perspectives illustrates an important premise of this report—that a full understanding of the Government-innovation relationship must involve an appreciation not only of the existing programs, but also of the industrial contexts in which their effects are felt.

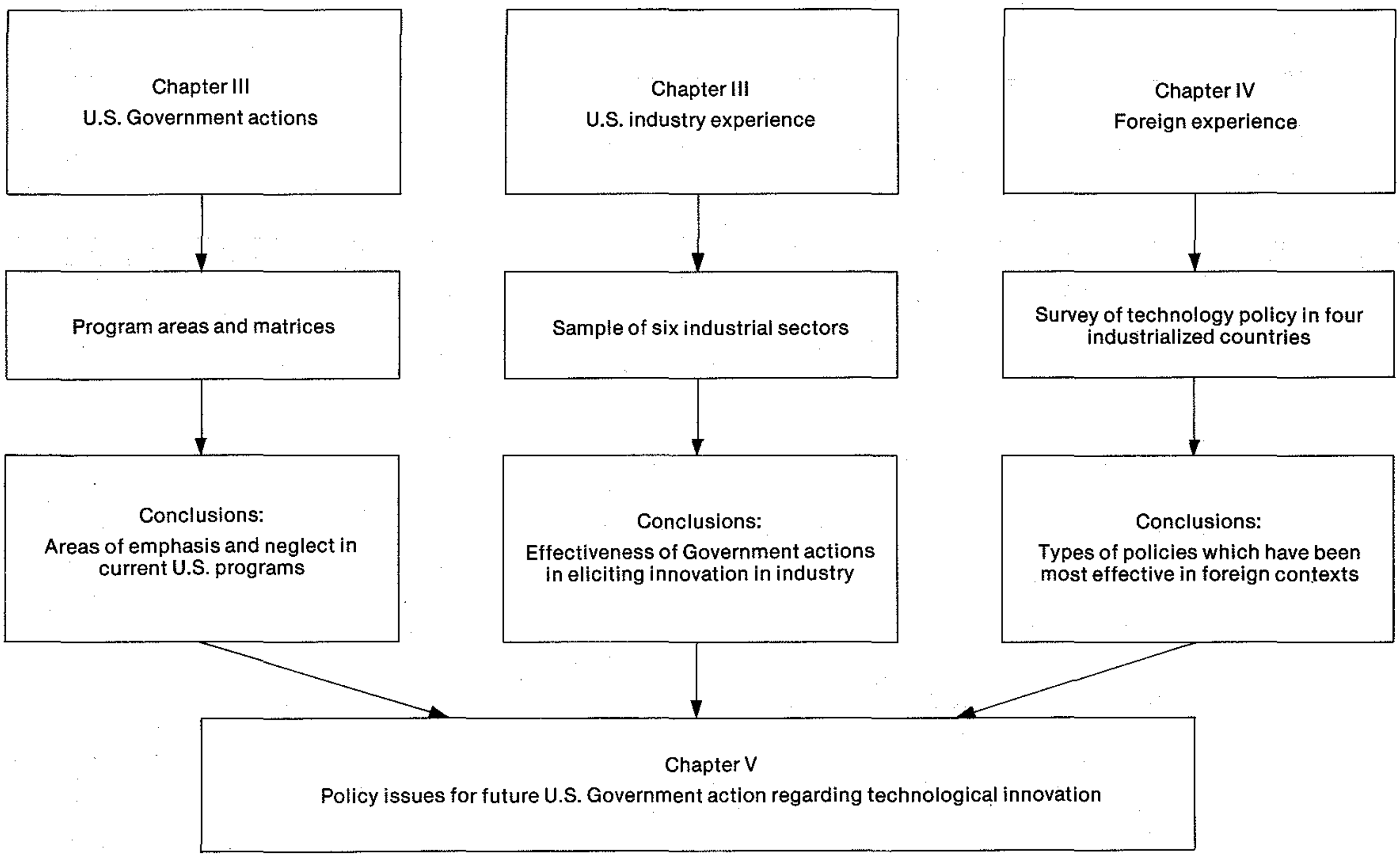
Although the presentation of each perspective contains a large amount of factual information, detailed analysis and evaluation have been eschewed in favor of a broad overview. This approach was chosen in order to be consonant with the overall focus of the report on the development of policy issues. Each of the perspectives has been utilized extensively as a source from which to draw in the development of the policy issues presented in chapter V. Figure 2 illustrates the components of this section and their relationship to the other parts of the report.

GOVERNMENT PROGRAMS

A Framework for Viewing U.S. Government Programs and Activities

The U.S. Government programs with which this report is concerned are those that have an important relationship to technological innovation. The number and variety of such programs are very large, and many, if not most, are not intended to affect innovation. On the contrary, the programs are directed toward a diversity of societal goals, some of which include: increasing the availability of goods and services for a variety of purposes, protecting society from the adverse consequences of technology such as endangerment of health and safety or dislocation of manpower, and designing measures benefiting specific sectors such as manufacturing, small business, labor, consumers, or the disadvantaged. These goals represent sometimes conflicting purposes, and the particular programs and activities directed toward them are undertaken somewhat independently of each other. Nevertheless, it is useful and necessary for conceptual purposes to establish a framework for organizing the Government programs and activities into a number of self-contained program areas which reflect the major technology-related themes of the programs that seem to be important or are at issue.

Figure 2.—U.S. and Foreign Experience
(Sources of Issues for Technological Innovation Policy)



SOURCE: Center for Policy Analysis.

A framework of this kind is valuable for several reasons. First, it provides a convenient construct for viewing the large number of relevant programs. Second, it illustrates some aspects of the programs' relationships to technological innovation. Third, it provides a common structure within which the proponents of various viewpoints can make their case concerning a reorientation of national policy in relation to technology.

PROGRAM AREAS

The framework developed for these purposes is presented below. The 13 program areas are listed in table 1. They have been organized according to the following logical sequence.

- Area I, *technology assessment,* is basic to policy design. Ideally, Government must be able to assess specific technologies with regard to their utility, unintended consequences (externalities), and the distributional consequences of both utility and externalities, if specific programs or activities are to be continued, altered, or initiated.
- Area II addresses the *direct regulation of the innovation process* through constraints on the research and development of new products and processes. Regulation here is intended to ameliorate the adverse consequences of technologies. The design of policy in this area is concerned with the problem of externalities and distributional consequences of possible adverse health or environmental effects.
- Area III focuses on *direct regulation of the production, marketing, and use of new or existing products.* The purposes and methods of regulation in this category do not differ substantially from area II. However, because regulation here focuses on end products rather than the development process, its impact on innovation is more indirect. The numbers of regulatory programs in this area are quite large and exceed those in area II.
- Area IV addresses the activities and programs that are intended to *enhance the development and utilization of technology for private goods and services where the private sector is the primary user.* The Government role in this area has traditionally been a relatively limited one.
- Area V concerns programs to *support technology in public services where consumers are the primary users.* In contrast to area IV, the Government role here has traditionally been rather large. Public goods and services such as transportation, communication, or law enforcement comprise the relevant programs.
- Area VI represents *technology enhancement activities where the Government itself (on behalf of the society) is the prime user.* This area would include programs such as the space and defense efforts.

The program areas II through VI all represent activities and programs that are undertaken in order to directly affect a perceived deficiency in resource availability, utility, externalities, or distributional consequences of technological activity. Areas II and III consist of programs in which regulatory means are employed to channel the direction of technology, and areas IV through VI consist of programs that utilize other mechanisms to enhance the development of technology. The remaining seven program areas represent activities that are less direct, though important for technological change.

- Area VII is the list of programs generally described as the necessary *infrastructure or science base required for innovation* to occur, for whatever purpose. This includes programs such as support for basic research, information transfer efforts, etc.
- Areas VIII and IX represent less technology-focused *policies, emphasizing policies directed toward industry and labor market structure* respectively, which nonetheless may affect technological change.
- Areas X and XI represent even more general *domestic economic and foreign trade policies* with possibly unintended or indirect effects on technological innovation.
- Area XII concerns programs that *create shifts in the consumer demand* for technologies. Various regulatory policies, user subsidies, and information transfer programs operate in this area as modulators of existing market forces and hence exert an im-

portant impact on the kinds of new technologies developed.

- Area XIII similarly concerns *worker demands* that are likely to influence the nature of new technologies. The demand for safe working conditions is one example.

The programs in areas II through XI all focus primarily on supply-side Government programs and activities, intending to affect what the industrial or labor sectors are able to deliver. In contrast, areas XII and XIII emphasize the demand-side policies directed towards enhancing the expression of consumer and worker demands respectively.

Because the 13 program areas reflect independent, and sometimes even conflicting, societal goals, there are difficult choices to be made concerning the relative emphasis among them. Accordingly, the choice of which areas deserve more or less attention is necessarily a political determination, which might be very different if made by those concerned primarily with industrial growth in contrast to those interested in environmental pollution. What the organizing of Government programs and activities into these 13 groups permits is a discussion as to relative policy emphasis that makes clear the priorities of the group proposing expanded or diminished attention to various areas. The categorization of activities into these policy areas should itself evoke little controversy and will allow the different perceptions of what deserves greater or lesser emphasis to be advocated within a common framework.

Identification of U.S. Programs

The following section identifies and categorizes existing U.S. Government programs that have an important relationship to technological innovation. This is done through the use of 13 matrices, each of which corresponds to one of the 13 program areas. The matrices were developed in order to illustrate something of the nature of the relationship between the programs and activities which comprise the policy areas and technological innovation. This is accomplished by the axis labels for each matrix. For example, in area I, which concerns technology assessment, the primary evaluative questions with respect to a new or existing technology—its utility, external effects, and the distribution of its effects to different segments of society—are listed on the horizontal axis. Similarly, in area IV, which concerns technology enhancement in the private sector, the various mechanisms for encouraging new technologies—transferring information, reducing cost, increasing the reward, etc.—are listed on the vertical axis.

For each program area, the matrix entries represent an attempt to identify the major existing programs and agency actions. Because many, if not most, Government activities are addressed to more than a single purpose, programs often appear in more than one matrix. It should be emphasized that although the programs listed clearly differ in terms of their size and effectiveness, information as to their relative weight is not contained in the matrices since the primary purpose of the matrices is to identify and categorize rather than to evaluate.

The matrices were a valuable tool to the analysis in several respects. First, they provided a convenient structure for categorizing the large amount of data gathered about the existing U.S. programs. Although the programs are listed without annotations in the matrices, substantial background research and analysis went into their categorization and the matrix development. This effort, though relied on to reach the research conclusions, is not presented in this report. Second, the matrices allowed the areas of programs emphasis to be highlighted, both among the 13 policy areas and within each area. Third, they furnished an analytical tool which was relied upon heavily in developing the major policy issues presented in the final section of this report. Those issues are all concerned with possible reorientations of existing national priorities.

The matrices were important, therefore, in suggesting where existing emphasis lies and what kinds of programs have generally been neglected. For example, in matrix IV, which concerns the encouragement of private-sector technological development, it became apparent from the categorization of existing programs that there is no major, across-the-board program in support of basic civilian technology. The realization that there is a lack of such a program, when combined with information about the foreign experience in this regard, led to the suggestion that new programs of this kind should be considered as a

Matrix I.—The Assessment of New and Existing Specific Technologies*

Reason for undertaking assessment	Subject matter of assessment: Utility	Externality	Distributional effects
Explicit or primary mission agency	• Full assessment studies: —OTA → —GAO →	→ → • Assessment as to safety: CPSC, NHTSA, FDA, OSHA, NRC • Assessment as to environmental effects: EPA (TOSCA), CEQ • Assessment as to inflation: CWPS	→ →
Incidental to primary mission, but a recurring function	• Part of cost-benefit or other program analysis or evaluations by mission agencies, e.g., DOT, DOD, NASA, DOE →	• Impact statements by mission agencies: —environmental (EIS) —economic (inflation) →	→
Ad hoc	• Special commissions or studies: e.g., NAS/NAE saccharin study → • Special studies by mission agencies, e.g., FCC electronic mail assessment, NSF funding	→	→

*OSTP is responsible for assessment or coordination of agency technology policies rather than assessing specific technologies.

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Matrix II.—Direct Regulation of the Research or Development of New Products and Processes

Manner of action	Purpose of Program: Control of health/safety hazards	Control of environmental hazards	Safeguard of national security
Outright suppression of R&D	• Research on highly infectious agents		• Nuclear weapons research
Limited granting of license/permit for R&D	• Research on certain radioactive materials (DOE)	• Research using fast-breeder reactors (DOE) → • Research on nuclear fuel reprocessing →	• Research on uranium isotopes separation (DOE)
Setting standards/ requirements for R&D	• Research using human subjects (HEW) • Pharmaceutical research (FDA) → • Pesticide research (EPA) → • Food additives → • Research on toxic substances (EPA) → • Medical devices (FDA)		
Setting guidelines for Federal funding of R&D	• Recombinant DNA research (NIH)		
Voluntary guidelines	• Recombinant DNA research		

Matrix III.—Direct Regulation of the Production, Marketing, and Use of New or Existing Products

Regulatory area	Commercial stage affected: Production	Marketing	Use
Pollution control	• Air pollution (EPA) —stationary sources —mobile sources • Water pollution (EPA) —effluent —drinking • Noise pollution (DOT, EPA, OSHA)		
Health/safety standards	• Workplace (OSHA) • Toxic substances (EPA) • Drugs (FDA) • Pesticides (EPA)	• Labeling —consumer products (CPSC) —pesticides (EPA) • Advertising control, e.g., cigarettes (FTC) • Consumer product safety standards (CPSC) • Automobiles (NHTSA) • Drugs (FDA)	• Pharmaceuticals (FDA) • Food additives (FDA) • Pesticides (EPA) • Transportation safety (DOT) • Radioactive materials (NRC)
Product specification	• Automobile fuel efficiency (EPA, DOE, DOT) • Appliance energy efficiency (DOE) • Coal conversion, energy conservation in manufacturing (DOE)	• Food inspection and grading (USDA, FDA, DOC) • Packaging and labeling specification (FTC)	• Communications regulation (FCC) • Building codes (HUD) • Product standardization (NBS)
Products liability	• Tort system →	→	→

Matrix IV.—Programs To Encourage the Development and Utilization of Technology in and for the Private Goods and Services Sector

Manner of action	Stages of innovation process: Market research	Technical research	Development/ engineering	Production and commercialization
Transfer of technology to the firm		• Antitrust regulations joint R&D (antitrust exemption) → —compulsory licensing • Tech. Util. Program (e.g., NASA, SBA) → • Diffusion program of R&D from Government labs → • Diffusion of R&D funded by Government (e.g., ASRA, NTIS) → • Agricultural extension services → • Government-university-industry cooperation (e.g., Sea Grant)		
Reducing costs of innovation		• Direct funding of R&D (e.g., DOE) • Tax treatment for R&D • Antitrust regulations → —licensing —joint R&D (SBA) • Compulsory licensing under Government procurement → • Agricultural extension services →	• Investment tax credits →	• Loans and subsidies for modernization (e.g., fisheries and shipbuilding)
Increasing reward of innovation		• Patent and license system → • Government procurement →		
Decreasing probability of commercial failure	• Government procurement • Provision of market information (DOC, SBA)		• Demonstration projects	
Decreasing probability of technical failure		• Provision of technical information (e.g., NTIS, other mission agencies) → • Invention evaluation (DOE/NBS)	• Demonstration projects	

Matrix V.—Government Support of Technology for Public Services* Where Consumers are the Primary Users

Manner of Government action	Element of innovation process affected: Market research	Technical research	Development and engineering	Production and commercialization
Reducing private sector costs	• Direct funding of R&D (e.g., EPA, DOE, DOT, DOC) →	→	→	
			• Provision of capital (e.g., COMSAT) →	→
Government performance	• Studies of consumer demand (e.g., DOT)	• R&D by national and agency labs	• Demonstration projects (e.g., DOT, DOE)	
Increasing private sector reward	• Government procurement →	→	→	→
	• Rate-of-return regulation (e.g., utilities) →	→	→	→
				• Regulations limiting entry (e.g., FCC, CAB)
Reducing probability of failure	• Government procurement specifications →	→	→	→
			• Demonstration projects	
Diffusion	• Publication of market studies (e.g., mission agencies)	• Technology transfer programs (mission agencies)		
Influencing demand				• Government user subsidy (e.g., tax incentives for home insulation) • Specification of approved products (e.g., medical devices)

*Program areas: Law enforcement, health, transport, communications, energy, education delivery, pollution control delivery.

Matrix VI.—Support for the Development of Technology Where the Federal Government is the Primary User

Manner of action \ Stage of innovation	Research	Prototype development or demonstration	Manufacturing/ production
Product procurement	• DOD (e.g., lasers) • NASA (e.g., space systems) • Other mission agencies (i.e., EPA, DOT, etc.) →	• DOD (armed services) • NASA (e.g., shuttle program)	• DOD (weapons procurement) • NASA (e.g., spacecraft components)
Support for R&D in the private sector	• DOD (mainly DARPA) • NASA • Other mission agencies →	• DOE (fusion research) • DOD (mainly armed services)	• DOD (e.g., ICAM program)
Performance of R&D by the Government	• DOD (service labs) • DOE (energy research centers, National Labs) • Other mission agencies →	• DOD (e.g., weapons development) • DOE (e.g., fusion, uranium enrichment)	• DOD (weapons procurement) • DOE (nuclear weapons)

Matrix VII.—Support for the Science Base Necessary for the Development of New Technology

Activity supported	Government action: Government performance	Government action: Government support
Education	• Military academy science programs (e.g., West Point)	• Fellowship program (e.g., NSF, NIH) • Military training programs in private institutions • Support of university research
Basic research	• NBS (e.g., laser research) • NIH → • NASA →	• NSF • DOE (e.g., high-energy physics) [NIH →] [NASA →]
Data compilation and validation	• Federal data banks (NBS) • Mission agencies	• Support for data compilation —as a component of overall scientific effort (NSF, NIH) —related to specific problems (NAS)
Dissemination of research results	• NTIS	• Support for scientific publications, conferences (NSF, NIH)

Matrix VIII.—Policies To Affect Industry Structure Which May Affect the Development of Technology

Aspect of industry structure affected	Nature of effects: Motivation to innovate — Increase	Motivation to innovate — Decrease	Ability to innovation — Increase	Ability to innovation — Decrease
Entry-exit	• Bankruptcy laws • Tax-loss provisions	• Compulsory licensing actions • Barriers due to patent rights	• Tax loss provisions	• SEC regulation
Competitive position of small firms	• Procurement ear-marked for small businesses	• Capital gains treatment • Access to venture capital (Sec. 144)	• Subchapter S (IRS code) • SBA loans, guarantees • SEC special exemptions • SBA joint R&D exemption	• Capital gains treatment • Access to venture capital (Sec. 144)
Relative market dominance of larger firms	• Holder's patent rights → • Government procurement • Antitrust laws →	• Compulsory licensing actions	• Government procurement • Antitrust laws →	
Collaboration among firms	• Antitrust laws →		• SBA joint R&D exemption • Antitrust laws →	

Matrix IX.—Policies Affecting Supply and Demand of Manpower Resources Having an Impact on Technological Change

Characteristic affected	Principal group affected: Employers	Employees	Educational institutions
Supply		• Retraining programs • Immigration policy	• Government-funded scholarships • Federal support for vocational and technical training
Demand	• Tax credit for new employment generated • Government procurement • Government-funded R&D		• Government-funded R&D
Price	• Minimum wage • Social security taxes • Tax credit for new employment		
Distribution	• Regional development incentives • Sectoral development incentives	• Tax provisions for moving expenses	
Mobility	• Tax credits for retraining programs	• Labor adjustment assistance • Industry-Government exchange programs	• Federal support for vocational/technical training

Matrix X.—Economic Policies With Unintended or Indirect Effects on Technological Innovation

Policy type	Area affected: Motivation to innovate	Area affected: Ability to innovate
Macro-economic policy	• Government budget →	→
	• Minimum wage legislation	• Interest rate
	• Social security taxes	
Capital market transactions	• SEC rules and regulations →	→
		• Banking regulations
		• ERISA provisions on venture capital investments
Regulatory measures	• Regulated rate structures (e.g., ICC)	
Tax policies	• Tax writeoff for losses →	→
	• Investment credit	
	• Depreciation allowance →	→
	• Capital gains preference	
	• Depletion allowances →	→

Matrix XI.—Policies Affecting International Trade and Investment

Area affected	Direction of effect: Tend to encourage	Direction of effect: Tend to discourage
U.S. import	• MFN status on tariffs • Adjustment assistant program —labor —business • Tariff concessions • GATT	• Tariff barriers (ITC) • Product safety standards (e.g., FDA) • Import quotas • Government procurement (Buy American) • Industrial standards • Antidumping duties • Countervailing duties • 200-mile limit on fishing rights • STR (Special Trade Representative)
U.S. export	• Government subsidies (e.g., on agricultural products) • Export exemption of product safety regulations • Tax concessions (DISC) • Export credits (EXIM bank, Commodity Credit Corp. of DOA) • Loan guarantees by EXIM bank to private credit sources (PEFCO, FCIA) • Tied foreign aid (AID) • Export promotional information service (DOC)	• Export Administration Act • Munitions Control Act • Trading with Enemy Act • Anti-Boycott legislation
U.S. investment overseas	• Tax credits on foreign taxes paid • Tax deferrals (e.g., subpart F income) • OPIC guarantees • Pollution and safety standards on U.S. plants • Transfer pricing control (IRS code 482) → • Allocation of R&D expenses (IRS code 1.861)	• Extraterritorial application of antitrust → (Transfer pricing control (IRS code 482))
Foreign investment in United States	• Mechanisms discouraging imports may encourage investment in United States • Exchange ratesetting →	• Pollution and safety standards on domestic plants → (Exchange ratesetting) • Industries closed to foreign investment (nuclear energy, communications, shipping)

Matrix XII.—Policies Intended To Create Shifts in Consumer Demand

Manner of action \ Policy purpose	Protecting health/safety	Protecting economic welfare	Other social purposes
Regulation of product characteristics	• Consumer products (CPSC) • Toxics, pesticides (EPA) • Food, drugs (FDA) • Food (USDA) • Cars (DOT)		• Energy efficiency standards: cars, appliances
Regulation market transactions		• Consumer credit regulation • Warranty regulation • FTC enforcement against deceptive trade practices • Advertising regulation, (e.g., corrective advertising)	
Information transfer	• Nutritional labeling • Warning labels (e.g., cigarettes)	• Food grading (USDA) • Regulation of credit • Warranty regulation • Fair packaging and labeling	• Energy labeling
Financial incentives			• Tax credit for pollution-control devices

Matrix XIII.—Government Policies Responding to Worker Demand Having Impact on Technological Change

Manner of action	Policy in response to: Demands for health/safety	Demands for economic welfare	Demands for legal rights
Regulation	• Working conditions: —OSHA —mine safety regulations	• Social Security benefits • Minimum wage • Protection of pension earnings (ERISA) • Raising retirement age	• NLRA
Government information transfer program	• OSHA	• Ajustment assistance (DOC, DOL) • Retraining	

major policy issue (see issue #1, chapter V). Similarly, an analysis of the programs in matrices II and III, which concern regulation, led to the realization that there are various approaches to regulatory design which have not yet been seriously attempted as a means of encouraging the development of new compliance-oriented technology. Some of these means were suggested as a regulatory policy issue (see issue #5, chapter V). It should be emphasized that the matrices did not provide the only input to the development of issues. On the contrary, the industry studies below and the foreign experience (chapter IV) were also important. The matrices did, however, furnish the principal structure for depicting and analyzing the existing U.S. Government effort regarding technology.

A COMPARISON OF SELECTED INDUSTRY EXPERIENCES

The industry-by-industry study presented in this section was undertaken to complement the policy-oriented approach described previously. On the one hand, it provides a needed "real-world" input into what would otherwise be a rather theoretical construct. Thus, not only does it serve to identify influential governmental policies, which might otherwise be overlooked (for instance, decisions concerning the allocation of the radiofrequency spectrum by the Federal Communications Commission that have had an enormous impact on innovation in the electronics industry),[1] but it also helps to order such policies according to the observed magnitude of their effect on innovation.

On the other hand, those policies, programs, or procedures that have an indirect or long-range impact, or that affect innovation primarily through their effect on the business environment within which firms innovate, are unlikely to be accorded their proper weight in a microcosmic study concentrating on a particular industry. Furthermore, examination of an industry that has fared relatively poorly in recent years is likely to bias the results toward those Government policies having a net negative effect on innovation, whereas the opposite may be true of industries whose track record is more favorable. In short, the two approaches—macroscopic by policy area, and microscopic by industry—are complementary and have quite different strengths and weaknesses.

Six industries were chosen for study:

- Aircraft and aircraft engines,
- Automobiles,
- Carpets,
- Synthetic materials,
- Iron and steel, and
- Semiconductors.

They were selected based on the existing resources of the Center and the need to include as wide a coverage as possible of the areas examined in the preceding sections.

The conclusions below are only a first step. Little evidence was available on consumer goods and services, and this was especially so when the primary question of the impact of Government programs and actions on innovation was raised. It would be most desirable to broaden the examples considered in a future comparison, beyond those of industrial goods and consumer durables listed above.

This section of the study has been based entirely on secondary sources; books, dissertations, and papers describing the various industries, which were chosen to reflect a long-term view of each industry and the effects on it of various governmental actions over a period, preferably, of several decades. Wherever possible, an attempt has been made to isolate those Government policies and programs that have had a clearly traceable effect on technological innovation in the industry under study, rather than, for example, those mainly affecting its structure or overall economic situation.

Certain limitations of this study must be identified at the outset. The most immediate of these stems from the relatively small number of industries examined. Many more could profitably have been studied, time permitting, and a sample more representative of the economy as a whole could have been obtained. Even within a given industry, this methodology may have emphasized certain forms of Government action over others perhaps equally important in the long run. The self-imposed limitation of examining only those actions that can be shown to have caused measurable change in the technological character of an industry's products or processes may understate long-term, indirect, and incremental effects. Thus, no mention is made of antitrust law as it has affected the automobile industry simply because an effect on technological innovation that flows from it cannot be clearly identified. Similarly, the impact on the industry of federally subsidized highway construction is easily substantiated, but its specific effects on innovation are difficult to document, and have not been included.

There are clearly gainers and losers from any innovation. A new product or process technology may strengthen some firms' competitive positions at the expense of others. Ancillary changes which are both positive and negative may also occur. Only the fact that an innovation occurred is examined here with no attempt to say that net results were positive. The weight of evidence in general supports the assumption that product and process innovation contributes strongly to the longrun vitality and viability of the economy.

Within the limitations stated, we are quite confident about the conclusions reported. Multiple sources of evidence were consulted in each case.

[1]W.R. Maclaurin, *Invention and Innovation in the Radio Industry* (New York, Macmillan, 1949).

Direct and documented relationships were sought, and for the most part the conclusions are supported by other independent studies.

A general overview of the six industries studied reveals the expected industry-to-industry differences, but also points up some striking similarities—particularly if attention is limited to those forms of governmental initiatives as described in policy areas III and VI in this chapter—that seem to be the most effective in inducing technological change. These three are:

- Regulation (pollution, health and safety, energy conservation),
- Federal R&D support (direct to industry, indirect, and performance by Government), and
- Purchase of innovative technology-based products.

Although other governmental actions (e.g., international policies) were identified that had an effect on technological innovation in some industries, and although certain industries (e.g., the carpet industry)[2] seem to have been relatively unaffected by any of the actions outlined above, these three stood out as the most important for those industries in which innovation has been most closely tied to Government action. In other words, these mechanisms were found to be the ones most effective in affecting the rate and direction of technological change in those industries most responsive to Government initiatives.

An earlier study of foreign experiences in encouraging innovation based on over 150 cases in five industries reached identical conclusions. One additional program, Government assistance in technology transfer, was noted as important in interviews conducted in Europe and Japan, but not mentioned prominently in the United States.[3]

The earlier work in Europe and Japan concluded that strikingly different patterns of government influence on innovation were apparent in the five industries studied. This is certainly true in the United States as well. Different actions and programs clearly are of vastly different importance in the six industries examined. Varying effects were also noted in newer as opposed to older firms in these industries, and consequently on different groups of employees, regions, and products. For example, defense procurement and Federal support for R&D in industry have shaped both the semiconductor and aircraft engine industries. Federal performance of R&D was also an important force in the latter case. Product regulation in the areas of emissions, safety, and fuel economy has shaped recent changes in the auto industry, while energy pricing policies have influenced synthetic materials—regulation of processes in the areas of energy conservation, safety, and environmental quality have been important factors in iron and steel investments and innovations. Also, higher minimum wages were held to have speeded introduction of new equipment in the carpet industry, while restrictions on wool imports hastened the use of synthetic fibers.

Actions that help new firms and ventures get started are highly effective in encouraging major innovations. Government purchases and support for R&D have been particularly important in this regard. For example, defense procurement and support for R&D stimulated the entry of new firms into the electronics industry in several ways, primarily through direct purchases. By providing an initial market and premium prices for major advances, defense purchasers speeded their introduction into use. The main contribution to the most important innovations in electronics and especially the development of integrated circuits seems to have been through this means.[4] A similar pattern of rapid technological advance, many new entrants, and economies resulting from production experience economies was evident for aircraft engines. The early establishment of air-cooled engines in the United States can be attributed to new entrants. None of the established engine manufacturers undertook the development of these engines until either persuaded to do so or extensively assisted by their governments.[5]

[2] Jinjoo Lee, *The Evolution of Technological Innovation in the Carpet Industry* (Cambridge, Mass.: MIT Center for Policy Alternatives working paper, January 1978).

[3] *National Support for Science and Technology: An Evaluation of the Foreign Experience* (Cambridge, Mass.: MIT Center for Policy Alternatives).

[4] James M. Utterback and Albert E. Murray, *The Influence of Defense Procurement and Sponsorship of Research and Development on the Development of the Civilian Electronics Industry* (Cambridge, Mass.: MIT Center for Policy Alternatives (CPA-77-5), June 1977).

[5] R. Miller and D. Sawers, *The Technical Development of Modern Aviation* (New York, N.Y.: Praeger, 1970).

Government procurement has played a significant role by establishing aircraft designers as commercial innovators. For instance, Douglas, which introduced the most successful DC-3 in the mid-1930's, spun off from Martin in 1920 and started as a military aircraft designer. Vickers developed the Viking and Viscount from experience gained from the Wellington bomber. Boeing was largely a military supplier before it built the 707, one of the first successful jetliners.[6]

These few examples certainly do not mean that encouraging entry through procurement would have a positive effect in every case. In a product area with little commercial growth potential, such a policy might simply lead to instability and greater uncertainty for the participants. The argument is that purchases by Government have great strategic leverage in stimulating innovations in many instances when this is understood and considered.

Actions that complement normal competitive pressures for change in an industry often appear to be more effective in promoting innovation than those that do not take account of market forces. For example, while the minimum standards for auto-emission control tend not to be exceeded, industry has met fuel economy standards well in advance of what has been required.[7] The difference seems to reflect the degree to which market forces and regulatory requirements are in concert in the case of fuel economy. In such cases industry is doubly motivated to innovate. Requirements for energy saving in steelmaking are also in line with the industry's competitive concerns with productivity and costs. As fuel is a major part of total production costs, conservation requirements and competitive forces have acted together to stimulate change.[8] Conversely, pollution-control regulations and the current tax treatment for pollution-control expenditures appear to have simply encouraged retrofits on existing facilities instead of investment in newer and more efficient technologies.[9]

There is a strong suggestion here that an effluent charge or heavy penalty above some minimum total-plant discharge would act in concert with competitive forces and encourage innovation, while a host of specific requirements work against competitive forces and also discourage innovation.[10]

Many creative departures from continuing incremental improvement of existing technology seem to be the result of firms' responses to crises. A crisis forces the firm to search in new directions for solutions. It can result in major losses and failures, but also can result in unexpected solutions. For example, a new process for making stainless steel using less chromium was introduced when imports of Rhodesian products were restricted. Also, steel firms joined together to develop new ore benefication methods when diminishing supplies of high-grade ore in the Great Lakes region threatened their economic survival.[11]

Some evidence suggests that direct regulation of products and processes may act as a crisis to accelerate major innovation.[12] For example, the use of electronic microprocessors to control auto engines is a major innovation to address needs for both fuel economy and lower emissions levels. New technologies sometimes open great potentials for expansion of their application and for improvements, in this case for other electronic automotive applications such as controlled braking. And it should be noted that while costs will be higher for automakers and consumers, a large market has been created for firms making microprocessors, sensors, new auto accessories, etc.[13]

The timing of regulatory interventions is critical regarding their influence on technology and in-

[6]Linsu Kim, *The Influence of Government on Technological Development in Aircraft and Aircraft Engines* (Cambridge, Mass.: MIT Center for Policy Alternatives working paper, December 1977).

[7]William J. Abernathy and Balaji S. Chakravarthy, *Technological Change in the U.S. Automobile Industry: Assessing the Federal Initiative* (Cambridge, Mass.: prepared for Department of Transportation, Transportation Systems Center, December 1977).

[8]Linsu Kim, *The Influence of Government Actions on Technological Development in the Iron and Steel Industry* (Cambridge, Mass.: MIT Center for Policy Alternatives working paper, January 1978).

[9]Joseph Mintzes, *Technology and World Trade: The Steel Industry*, a paper prepared for OTA, May 19, 1977.

[10]W.J. Vaughn, C.S. Russell, and H.C. Cochrane, *Government Policies and the Adoption of Innovations in the Integrated Steel Industry* (Washington, D.C.: Resources for the Future, 1976).

[11]Kim, 1978, op. cit.

[12]Thomas J. Allen, et al., "Government Influence on the Process of Innovation in Europe and Japan," *Research Policy*, (in press).

[13]George White, "Management Criteria for Technological Innovation," *Technology Review*, February 1978.

novation. Unless the needed infrastructure, such as trained people, is in place or created concurrently to meet the requirements, severe dislocations may result. Structural unemployment and compensation of employees displaced by mandated major changes is a continuing concern. The implication is that a steady and gradual pace of mandated requirements is advantageous in this respect.

This report does not argue that regulation necessarily leads to more economically efficient or commercially desirable allocations of resources. Moreover, regulation may sometimes impose sufficiently high costs and stringent constraints that innovation is impeded. Nevertheless, there are many examples of innovations enabled or enhanced by regulation. When regulation of products and processes is required for health, safety, or other purposes, it was found that potentials often exist for effective and innovative technological solutions. This should be considered in decisions about the timing, form, and implementation of regulatory actions.

Government actions often have unintended effects on innovation, and several programs together may generate unexpected effects.

- Intense pressure for rapid change may force industry to patch up an existing technology rather than risk the failure of a radical innovation.[14]
- Stringent requirements for approval of new products may act to reduce competition from new producers and new entrants in a business, thus increasing the value to firms of established and accepted products.
- At the level of detailed design changes, Federal laws or regulations have been found to act as a constraint to innovations about as frequently as they act to stimulate change. And if regulations are not continually updated to reflect changing possibilities, they may greatly reduce potentials for improvements.[15]
- An implication is that performance specifications would generally distort potential improvements to a lesser extent than would specification of specific technologies or solutions.[16]
- Major innovations have drastically reduced the total costs of ownership and use of major appliances, aircraft engines, and electronic systems, but this was not readily apparent at first. Undue stress on cost improvement might discourage seemingly costly new technologies which have dramatic potential for savings in the longer run.[17]

There is evidently potential for damage as well as benefit in many Government programs and actions that influence technology. In this respect a special note should be made concerning the Federal role in actually performing research and development. The evidence reviewed strongly indicated that large projects directly performed by Government for the development of products and production process equipment have been quickly made obsolete by the rapid pace of innovation in industry, and their results have not found widespread use. This was true of projects to develop compact proximity fuses based on vacuum tubes, of development of equipment for automatic production of transistor-based circuits, of projects to develop several liquid-cooled aircraft engines, and so on.[18] Similar cases are evident in the United Kingdom and Germany. One reason for this appears to be the firms' superior knowledge of critical details of the production process, its interaction with product design, and a multitude of important adjustments in both. Conversely, Government performance of more basic research had evidently made outstanding contributions to industrial innovations. This seems to be true for example, of basic work on aerodynamics, high-temperature liquid cooling, improved aviation fuel, and other areas of general usefulness which, however, do not yield proprietary advantage.[19]

Design of programs and analysis of the effects on innovation of Government programs and actions should recognize that there is no simple connection between cause and effect. Actions

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[14]Abernathy and Chakravarthy, 1977, op. cit.

[15]A.H. Rubenstein and John E. Ettlie, "Analysis of Federal Stimuli to Development of New Technology by Suppliers to Automobile Manufacturers," *Final Report to U.S. Department of Transportation*, March 1977.

[16]R.O. Schlaifer and S.D. Heron, *Development of Aircraft Engines and Fuels* (Cambridge, Mass.: Harvard University Press, 1950).

[17]Utterback and Murphy, 1977, op. cit.

[18]Ibid.

[19]Kim, 1977, op. cit.

can have multiple effects. Many actions can contribute to the same effect. Several actions can interact to produce a disproportionate effect. The net result or bottom line so to speak is not always clear. For example, early support given to semiconductor technology through development contracts, direct procurement of prototypes and early production at premium prices, dramatization and demonstration of the military need for greater performance and reliability, and a willingness to encourage new and unproven suppliers all promoted entry of new firms. But their relative importance seems to vary widely in the case of different firms. Similarly, reductions in prices for electronic components appear to have been caused by a variety of factors: the development of production lines for "industrial preparedness," direct and indirect procurement of a high volume of electronics components, encouragement of entry, competition and development of "second sources," and occasional decreases in purchases by the military. By the same token, manpower development and mobility were also affected by many different actions.[20]

No one policy or technique can be recommended as a key to effective stimulation or support for change. Many factors, including availability of private venture capital, can contribute to entry of new firms and enhance the climate for major product innovation. These may be supported by other conditions such as the supply and mobility of key personnel, Government encouragement of competition, and so on. Several factors might be considered as a set of loosely coupled active elements rather than one being cause and the other effect. Lack of balance or a lack of one critical factor may be seen as a "barrier" to innovation.

Finally, sophisticated control of program implementation has apparently enhanced the influence of many Government programs and actions. Should funds be concentrated on one firm or spread among many? Should established firms be supported or should new entrants be encouraged? Should suppliers of advanced components be supported as well as users of such components in final systems or products? Should specifications be based on an informal understanding of best performance or best effort, or should they be rigidly detailed? Should standardization be stressed, or should diverse parallel approaches be taken? Each of these conflicting options, among many others, has been effective in certain examples. Apart from the content of the program, careful timing and implementation can greatly enhance its impact.

In conclusion, Government programs and actions that affect innovation have widely varying effects in different industry and technology contexts. Timing, interaction with other programs, and the details of implementation are often crucial. This has been well-understood in many successful past developments for national purposes going back from well beyond early encouragement of the radio industry and Government pressure for four-wheel brakes on autos to contemporary examples such as integrated circuitry, numerically controlled machine tools, emission controls, etc. Understanding of the dynamics of different industries is needed in order to promote positive and avoid negative impacts. Similarly, what industry can and should do with respect to innovation can not be judged independently of Government action. Since we are beginning to recognize the many areas in which Government and industry are closely interdependent, Government actions must be designed with a greater appreciation for industrial potential and responses. This will require study of more industries, product areas, and services. We need to understand industry organization, decision-making, and responses with greater generality and subtlety. A program of active experimentation and study in cooperation with industry is needed to provide an environment conducive to more creative technological advance.

[20]Utterback and Murray, 1977, op. cit.

Chapter IV

SUMMARY OF MAJOR FEATURES OF SEVERAL FOREIGN APPROACHES TO TECHNOLOGY POLICY

Chapter IV

SUMMARY OF MAJOR FEATURES OF SEVERAL FOREIGN APPROACHES TO TECHNOLOGY POLICY

Foreign experience can offer several useful lessons as to why and how specific policies succeed or fail under a given set of circumstances. In effect, it provides a testing ground for policies in action that can be instructive to the analyst. On the basis of extensive studies previously undertaken by the authors on the policies of several foreign countries, both developed and underdeveloped, the following review highlights the major thrust of policies in four technologically advanced nations. The reasons for this selection are that each case illustrates either some similar factors that are present in the U.S. environment or some contrasting approaches that might be instructive. While there is no implicit suggestion that the United States could or should employ similar techniques, the purpose of the analysis is to outline the objectives that have tended to dominate foreign technology planning.

The Gilpin report to the Subcommittee on Economic Growth of the Joint Economic Committee[1] argued that the most distinctive example of differences in approach are those of Japan and the United Kingdom. The former is commonly cited as an illustration of a highly successful pursuit of technological growth while the latter demonstrates policies that have had disappointing results. The Gilpin report observes that these cases are interesting not simply because of their contrast, but because of their relevance to the U.S. position today. On one hand, there is a tendency to pursue policies in the United States, which have not been successful abroad, notably in the United Kingdom. On the other hand, the Japanese example, which for so long has been dismissed as irrelevant to U.S. circumstances, appears to have an increasing number of useful lessons to American policymakers.

The following paragraphs offer an overview of the principal thrust of the major national programs, including the original or innovative features of those programs.

JAPAN

It is clear that the unique circumstances of the Japanese industrial environment have accounted heavily for Japan's successful exploitation of technology. The tightly organized industrial structure, the government-industry-banking partnership, the weight of government direction of economic activity and the notable self-discipline of Japanese entrepreneurs and workers are always cited.

The distinguishing feature of Japanese technology policy as such has been its total and complete identification with economic growth policies. The use and development of technology have been the backbone of industrial growth. Low-technology and inefficient industries unable to compete with firms in the developed Western

[1]Robert Gilpin, *Technology, Economic Growth, and International Competitiveness*, a report prepared for the Subcommittee on Economic Growth of the Joint Economic Committee, U.S. Congress (Washingotn, D.C.: U.S. Government Printing Office, 1975).

countries have been allowed to die out rather than be protected. Protective policies have been employed only to the extent that they aid the development of infant or emerging high-technology industries. The Japanese government has made a distinction between its treatment of large business enterprises and small business. The role of both is recognized as important in the industrial structure. Whereas the larger firms may appear to spearhead Japan's export drive, the government nevertheless has a strong policy for the technological and business infrastructure support of the small firm.

Japanese policy has stressed the commercialization of technology in the economic growth process. Until very recently, little R&D funding emanated from the government. In fact, the government's role in technology and innovation has been highly indirect. R&D and its commercial development has been left to industry while the government has concentrated heavily on creating the environment for its industry to operate in.

Government "technology policy" thus has consisted principally of the following elements:

- Heavy emphasis on technical education and training highly skilled manpower resources available to industry.
- Emphasis on consumer technologies responding to market demand, as opposed to investments in basic R&D, "big science," and national prestige projects.
- Strong export orientation of the economy with the resulting need for Japanese firms to compete with the most technologically advanced international firms.
- Careful manipulation of the industrial structure to prepare sectors and firms to meet international competition; limited protection of infant industries until prepared to compete; and elimination of technologically weak companies.
- Avoidance of technology monopolies by Japanese firms by mandatory licensing to competitors of firms attaining dominant market positions.
- Government support for industry through analyses of export markets and available foreign technologies.
- Tax credits and deductions for industrial R&D and accelerated depreciation for pilot plants and R&D facilities.

GREAT BRITAIN

The British example contrasts sharply with the Japanese in most respects. First, the circumstances underlying innovation have perhaps played a role as important in the weakness of British technological policy as it has in the success of its Japanese counterpart. The positive industrial-financial-government partnership which has been the key element of Japanese strength has been far less present in Great Britain. Similarly, British technology policy has had less relation to the economic growth strategy of the government.

British government policy has focused heavily on supporting R&D efforts in basic fields. On one hand, this orientation has made it possible for the British to make major contributions to science and technology, in particular, areas of big science such as defense, nuclear energy, and space. On the other hand, this emphasis has been heavily on the supply-side with lesser attention given to market demand (at home and abroad) for the products of current research or to the problems faced by British industries in commercializing promising new technologies.

The British government, rather than the private market, has tended to make most of the key decisions on technologies to be developed by the country. Reliance on and support of private sector initiatives have not been key features in the British experience. Industry-wide research associations have been fostered by the government to respond to the needs of the private sector, but they have not had a major impact on private firm behavior.

Outside the public sector itself, the government has concentrated on the university system to expand the country's technical and scientific base of knowledge. Although the universities have developed strong programs in basic science, there has been a minimum of spillover effect into industry.

Finally, the British have not followed a strong manpower policy, as several other developed countries have done, to prepare technical personnel specifically for the needs of industry and technological change. The environment has been marked by poor relations with the labor force, low worker mobility, and strong worker resistance to change.

Several programs, however, merit close attention as important experiments by the government to bring technologies to the commercial stage. The National Research Development Corporation (NRDC) has been closely watched as an interesting experiment in government-industry partnership with relatively favorable results, while the Launching Aid program raised high expectations but fewer results. The Preproduction Order Support Program has produced interesting results in bringing advanced equipment already developed into commercial use.

- The NRDC has been the subject of close observation due to its unique character and the interest that other countries have shown in the experiment. NRDC is a public corporation (divorced form direct government management) supporting innovation via several activities, either (a) by paying part or all of the development costs, (b) by licensing public sector technologies, or (c) by entering into joint ventures with national private companies. The NRDC is a modest undertaking but a relative success. Its main success has come through its exploitation of public sector technologies especially those coming from the universities and research councils.
- Launching Aid has had as its objectives the reduction of commercial risk facing manufacturers by interest-free loans to the developer, repayable as a levy on sales or licenses. Unlike NRDC, this program has not been marked by significant success. Its investments have flowed primarily into government-designated projects rather than private market initiatives.
- The Preproduction Order Support Program aims at encouraging industry to utilize advanced equipment on a loan basis from the government with the option of purchasing the equipment after a trial period. The Department of Industry buys equipment from the manufacturer and lends it to selected industrial users. This program has shown some success, particularly in the machine tool industries, where the program, in effect, aided in introducing numerically controlled machine tools.

FRANCE

French policy, much like that of Great Britain, has been characterized by heavy government support of civilian technology. This is particularly true of both governments' commitment to heavy investments in big technologies such as computers, aircraft, and nuclear energy.

Consistent with France's highly centralized administrative structure, French science and technology policy is characterized by strong direction and control and a measure of long-range planning. Most technology policy has been dictated by France's political commitment to industrial and technological independence. The objective of maintaining at least one domestic supplier in every important industry—a policy requiring extensive government subsidies, frequently to weak industries—has had mixed results in stimulating innovative entrepreneurial behavior.

French policymakers have linked technological and economic growth policies more closely than the British. Great emphasis has been given to strengthening the industrial structure in France by encouraging mergers of companies into stronger national entities to respond to foreign competition. Strengthening the technological base of these firms has been a key objective. Similarly, the French have emphasized the importance of firm participation in the training of manpower resources.

The main outline of the French programs is as follows:

- "Concerted Action Programs"—with committees created to coordinate research in specific areas.

- "Thematic Action Programs"—designed to coordinate interdisciplinary applied research among laboratories normally undertaking basic research projects.
- "Pre-Development Aid"—helping research organizations launch work on new technologies.
- "Development Aid"—providing loans to meet development costs of private firms.
- "National Agency for the Valorization of Research" (ANVAR)—assisting researchers, inventors, and small firms in developing innovations.
- Tax Incentives
  - — all operating R&D expenses fully deductible costs,
  - — accelerated depreciation of R&D facilities, and
  - — tax deduction of capitalized R&D resources in a new organization
- Worker Training—payroll tax for worker retraining programs.

WEST GERMANY

Unlike France, Germany relies far more on market forces and industry-government-university cooperation than on regulation and control by the government. Government assistance is normally granted only where the market is expected to be sufficiently strong to guarantee the success of the program. As a result, German aid tends to focus on influencing the "climate" for innovation through indirect measures rather than designating or promoting specific development of technologies. However, a notable exception has been the German government's direct role in developing major technologies (electronics, computers, etc.), much as in Britain and France.

A positive factor in the German environment for innovation is the relatively high level of cooperation that exists among industry, universities, and government. Largely due to this factor, government action is not directed to stimulating joint programs as much as in France, for example. The principal German policy orientation is in efforts to reduce the costs of R&D for private firms and encouragement of large technically based corporations in advanced technological areas.

Several programs are of particular interest in the German case:

- Extensive network of research institutes largely supported by federal and state governments, ranging from basic research (e.g. Max Planck Institutes) to applied industry-oriented research (e.g. AIF—Industrial Research Organizations).
- Priority programs including the "big science" programs and the "key technologies" program; the later is focused specifically on R&D for industrial innovation and includes direct government cost-sharing with industry.
- The "first innovations" program consisting of interest-free, forgivable loans whereby the government meets 50 percent of the cost of commercial development of a new technology. If the effort fails, the loan is cancelled.
- Venture capital through an independent consortium of banks (WFG) supported by government guarantees under which the consortium purchases equity shares in new companies undertaking innovative projects.

SUMMARY OBSERVATIONS

On the basis of the previous four cases and several other studies,[2] the principal elements that tend to emerge in observing the foreign experience are the following:

1. Direct government support of R&D in firms—by varying degrees, most developed countries provide facilities (direct, indirect,

[2]*The Current International Economic Climate and Policies for Technical Innovation*, by Science Policy Research Unit, University of Sussex, United Kingdom, in collaboration with Staff Group Strategic Surveys TNO, The Netherlands.

or both) to encourage R&D functions within private firms.

2. Use of government demand through procurement policies has the effect of reducing risk and uncertainty for the innovative firm and as such constitutes one of the most effective tools of most industrialized countries in stimulating technological change.

3. Provision of capital by the government to firms desiring to introduce innovative products or processes to the market. Most countries have programs to meet the capital needs of private firms, either by venture capital corporations that buy equity shares in the firms or by direct government "start-up" funding available to firms introducing new technologies.

4. Concern with industrial structure—most developed countries have seen the necessity to force or encourage industrial restructuring to meet the requirements of rapid growth and international competition with technologically advanced firms. This has been accomplished through mergers, formation of public companies, elimination of technologically weak firms, and limited protection for emerging technologically weak and technologically oriented firms.

5. Emphasis on export capacity and international competition. All four countries discussed have viewed technological progress as an essential element in capturing new export markets and foreign competition as an important impetus of technological change.

6. Emphasis on labor-training and manpower development policies as a key feature in technological development. Most developed countries view the quality of manpower skills as their direct responsibility in strengthening the conditions for technological change.

Chapter V

MAJOR ISSUES IN U.S. POLICY TOWARD TECHNOLOGICAL INNOVATION

Chapter V

MAJOR ISSUES IN U.S. POLICY TOWARD TECHNOLOGICAL INNOVATION

This chapter presents a series of policy issues concerning the relationship between Government action and technological innovation which are, in the authors' view, major questions deserving of congressional attention in the near future. The articulation of these issues is intended to provide a critique of existing U.S. programs and policies in relation to innovation and to provoke debate about how existing policies might be reoriented. It should be acknowledged from the outset that the choice of these issues was at least partially subjective. Thus, reasonable people will undoubtedly differ about how important they are for congressional attention. It is not meant to imply that these issues are necessarily more important than other national priorities. Rather, they are intended to suggest a series of new initiatives that merit consideration in reassessing existing technology-related policies.

Although the issues involve subjective choice, the process for arriving at them was rooted in objective research. Thus, they derive principally from the three major elements of this report, the survey of existing Government programs, industry studies (chapter III), and foreign experience (chapter IV). The survey and categorization of existing U.S. programs furnished a framework within which to understand the relative emphasis among major policy areas and, within each policy area, to uncover what kinds of policy mechanisms have been employed most frequently for various purposes. From this survey it was possible to derive policy areas and mechanisms which, although now relatively neglected, may deserve additional attention in the future. The industry studies, on the other hand, provided information about how existing programs have actually affected innovation in those industries and therefore offered guidance as to what kinds of new or modified Government actions are likely to be effective in different contexts. Finally, the survey of foreign experience offered case studies of effective and ineffective techniques employed by other governments to encourage their private firms to innovate (see figure 2).

The purpose of this chapter, therefore, is to define these major issues, articulate why they appear to be important, and then to suggest a series of alternative policies which address the issues in various ways. The alternatives suggested are not meant to be an exhaustive list, nor is advocacy intended. They are suggested in order to illustrate the action potential inherent in each issue. It is intended that the focus of debate will be primarily on the issues themselves and only secondarily on the possible alternative actions.

ISSUE 1
Direct Support of Nonmission-Oriented Technology

Should Congress consider providing for the direct support of nonmission-oriented technology?

Direct Federal support for technological innovation has traditionally taken one of two forms in this country: general support for research and development, such as that funded by the National Science Foundation (NSF), and support for technology development (through R&D funding and the procurement of innovative products) in furtherance of certain well-defined national goals, such as the defense and space missions, and more recently the search for new sources of energy (see program areas IV, V, VI, and VII in chapter III).

This policy differs markedly from the practice and procedures of other technologically advanced nations, notably Japan, in which the governments support technological innovation with no other goal than the general economic one of helping particular sectors of industry to grow and to compete in international markets (see chapter IV).

Increased attention has recently been focused within the Government on ways in which, in cooperation with the private sector, it might seek to stimulate and encourage technological innovation through programs of direct support of some kind. There are three basic reasons for the heightened interest in such programs. First, the United States is facing increasingly stiff competition in technology-based products from other nations that have programs for domestic support of technological innovation for purely economic purposes.

In addition, the social returns on technological innovation are often greater than any reasonable expected private return, due to the inappropriability of some of the benefits, which makes a Federal sponsorship role appropriate (see chapter II). Lastly, there are purely social reasons for supporting innovation. An example of these is the general desirability of creating employment. Support for new development with specific manpower benefits in mind may involve both technological innovation and job redesign, and differs from the application of traditional labor market policies (discussed in issue #6). Technological innovation may also be supported for reasons of environmental protection or product safety.

If the Federal Government were to adopt a policy of broad support for technological innovation, the question would arise as to what type and degree of Federal intervention is appropriate and necessary at each stage of the innovative process. In attempting to answer this question, reference has been made to government programs in other countries (see chapter IV), as well as a study of some of the domestic effects of U.S. Government actions on a selected group of industries (see chapter III). There are two general conclusions that can be drawn from these sources. On the one hand, it was found that indirect effects of Government action can be extremely efficient in promoting technological change in specific industries, even when such effects are unintended.[1] On the other hand, as a general rule, direct Government support for technology tends to be more effective in the early stages of development, rather than later when the technology nears commercialization (see issue #2).

The potential effectiveness of the procurement process to stimulate and encourage innovation in the private sector was particularly borne out by the industry studies performed for this report. Indeed, the purchase by the Government of new, innovative products was found to be one of the most efficient stimulants of new technology. That procurement could be used to enhance innovation was recognized by the Commission on Government Procurement, and was embodied in some of the recommendations in their 1972 report to Congress. Many of these recommendations, in turn, have been included in legislation now before Congress.[2] Nevertheless, the recognition is lacking that procurement expenditures may in certain circumstances constitute a more efficient alternative to direct subsidy of R&D.

Another weakness in present policy results from the fact that there is at present no Federal agency charged with the mission of assuring the technological health and vitality of American industry generally. As a result, there is no focus in

[1]For example, the carpet industry's adoption of synthetic fibers was stimulated by the 1950 ban on the import of Chinese wool. See chapter III.

[2]S. 1269 the Federal Acquisition Act.

the Government for the support of general, nonappropriable research related to this broad mission. (The Directorate for Applied Science and Research Applications (ASRA) at NSF may do some of this, but only as a secondary mission for the agency, and on a very small scale.) For example, the Department of Energy supports research in basic nuclear physics, and the Defense Department supports laser research, because these are fields related to the missions of these agencies. However, there are other scientific fields, for example, the study of friction, corrosion, mechanical design, catalysis, manufacturing technology, etc., that are relevant to a wide variety of industrial processes, but for which no agency feels responsible.

Increased Government support for technology basic to commercial development is not likely in the majority of cases to result in patentable inventions; however, in those instances where patents might arise, there is an issue as to who should own the patent rights to inventions stemming from publicly funded R&D. The situation regarding this question is currently quite chaotic. Each of the various mission agencies has, over time, adopted its own procedures in dealing with the issue, and the result is that there is no uniform treatment in the Government either in policy or in its implementation. The effectiveness of patents, either in promoting innovation or in stifling competition and thereby retarding it, differs from industry to industry. However, studies[3] have shown that, in general, patents held by the Government and licensed only on a nonexclusive basis are used much less often than those in the private sector. Of course, there are social goals other than that of promoting innovation, and the granting of a monopoly license to manufacture and market a product developed in part with Federal funds may conflict with these. However, from the restricted viewpoint of this analysis, the conclusion is clear: a policy of refusing exclusive patent rights to federally funded inventions has a retarding rather than a stimulating effect on innovation.

The preceding discussion suggests the following options for possible congressional action.

[3]See the Government Patent Policy Study performed by Harbridge House for the Federal Council on Science and Technology, May 17, 1968.

1. Initiate a policy of selective procurement of products embodying innovative technology at prices that reflect the R&D costs incurred by the innovator. Such purchases of innovative products, by creating a market, may do more to stimulate innovation than would an equivalent expenditure of research funds.

   — This strategy is most likely to succeed in those situations in which a commercial market exists for the product, the technology has matured, and the price has dropped.
   — Procedures for dealing with the problem of monopoly creation might include parallel funding of several firms, or mandatory licensing by firms that capture a set fraction of the market.[4]

2. Establish a funding capability for the support of advanced, nonappropriable research responsive to a wide variety of societal needs, such as energy conservation,[5] or manufacturing productivity. The research could focus on technical subjects of wide applicability such as product fatigue, safety friction, corrosion, catalysis, etc.

   — A program could be set up either as a separate agency or as a function within an existing agency to monitor and fund nonappropriable research in fields of interest to a wide variety of industries.
   — Microeconomic analysis suggested in issue #8 would enhance the ability of this program to concentrate on those technologies of interest to specific industrial sectors, and specific manpower and environmental needs.

3. Grant, under appropriate safeguards,[6] exclusive patent rights to inventions made by private individuals or firms under Government funding, as in Europe and Japan.

   — Requiring guarantee of an intention to work the patent.
   — Avoiding the creation of a monopoly, for

[4]See chapter IV for a discussion of Japan's handling of this problem.

[5]The Advanced Technology Assessment Program of the Department of Energy does some of this on a very small scale.

[6]Bill H.R. 6249, the Uniform Federal Research and Development Utilization Act, addresses the issue.

example through "march-in rights" by which the Government may revoke exclusive patent rights.

ISSUE 2

Reconsideration of the Role of the National Laboratories

Should Congress consider the appropriate role of the National Laboratories in the support of technological innovation?

The question of the proper use of the federally owned and funded research institutes—in-house laboratories, national centers, and federally funded research and development centers (FFRDCs), which we refer to here as "National Labs"—is becoming a more and more critical issue, both for Congress and for the executive branch, as Government research activity expands into traditionally private domains (e.g. energy) and as the number and influence of the Labs grow commensurately. Indeed the Office of Technology Assessment (OTA), through its R&D Policies and Priorities Program, has been studying this issue, and has issued a draft report (National Laboratories Issues, May 9, 1977), which explores its implications thoroughly.

There is no doubt that the National Laboratories can perform a very useful role in undertaking research of broad social benefit, but which is unlikely to be performed in the private sector. Examples of such research might include work done to demonstrate the feasibility of specific pollution control technology, or investigations of alternative methods for the storage of radioactive waste products.

Nevertheless, there is significant doubt as to the advisability of involving the National Labs in the development of technology of immediate commercial significance because they are not closely attuned to the market. A strong conclusion which emerges from an examination of actual industry responses to governmental initiatives, both here and abroad, is that direct Government funding or performance of R&D is generally unsuccessful in creating commercially useful technology when it is applied to the later usages of the innovative process.

In addition, experience has shown that the problem of "spinning off" a new technology to the private sector at the appropriate stage is a very difficult one. Lastly, involvement of the National Labs in technology of commercial significance creates a bias toward in-house performance because of the competition engendered between them and privately owned research facilities, and the political difficulties sometimes encountered by an agency in locating large programs in specific private firms. The problem of competition can become serious when a National Laboratory serves a dual role as research facility, and as contract monitor or proposal evaluator.

The problems inherent in the competition between Government-owned and private R&D facilities, and their potential for inhibiting innovation, have been recognized by the Office of Management and Budget,[7] and more recently by the OTA study referred to above. The issue has not yet been dealt with effectively by legislation. Appropriate congressional actions might include the following:

1. Develop an explicit set of guidelines for use by the research funding agencies in deciding which projects to fund in-house and which to support in the private sector on the basis of:
   - Time-horizon of research,
   - Potential for commercial application, and
   - Direct utility to mission of sponsoring agency.
2. Cooperate with the executive branch, to define explicit missions for the various National Labs, in keeping with the overall mission of their sponsoring agencies in order to:
   - Clarify goals to facilitate performance evaluation,
   - Control mission expansion beyond original boundaries without congressional oversight, and
   - Possibly reduce the scope of National Lab activities so as to eliminate programs that would be more productive in the private sector.

[7]OMB Circular A-76, as revised, sets forth the general Federal policy of relying on the private sector, and lists a number of restrictive circumstances that must apply to justify the Government providing an industrial or commercial product for itself.

3. Cooperate with the executive branch in developing new roles for the National Labs, in performing research of broad social benefit that is unlikely to be undertaken in the private sector.

ISSUE 3

Facilitating New Entrants Into the Market

Should Congress consider measures to facilitate the entry of new firms and inventors into the market as a means of encouraging the introduction of new technologies and innovative entrepreneurship?

Technological innovations are frequently brought to the market by new firms or inventors who translate a new idea into a commercial venture. Similarly, new or small firms often have the flexibility to adapt easily and effectively to new and innovative ideas. It is important therefore that the entry and survival of new firms in the private sector be facilitated.

The relationship between technological change and new ventures may be seen from two perspectives. First, a new firm may be the direct result of a technological innovation by, for example, an individual inventor who decides to bring his new product into commercial use or an individual or group of individuals in an older, more established firm who decide to spinoff a new company founded on a new product. The older enterprise may even decide to create a new firm as a more appropriate vehicle for introducing a new technology.

Second, the characteristic of "smallness" or "newness" in an enterprise may offer the firm greater flexibility in experimenting with new ideas or processes. Production processes are less well-established and capital equipment is frequently more all-purpose. The new firm has no established market image that must be maintained and therefore may be more inclined to assume commercial risks in its effort to gain a market niche. This does not imply that older firms are by nature less capable of innovative activities than the new, smaller firm. Rather, the perceptions of risk and long-term gain may be different at the margin, with the small entrepreneur more willing to act on a new idea or product, which will differentiate him from larger, more powerful producers.

Ease of entry of new firms in the free enterprise system is an obvious economic as well as social objective in the United States. The ability of firms to enter and leave a market is a critical feature of an economic system with a sound competitive environment. This report emphasizes another dimension to this picture, i.e., that there is a strong technological objective as well in policies to assist the entry of new firms. New technologies with the potential of significant commercial use should not be kept from the market by unjustified structural, financial, or legal barriers. Yet the authors believe that the current U.S. industrial and financial structure does—even if inadvertently—impede easy entry of many potential new firms. Several examples of types of barriers that might be expected to face would-be entrants are:

Venture Capital Restrictions

The new entrepreneur frequently requires outside capital to launch his operation. This must be obtained through the private or public market. The Securities and Exchange Commission regulations (particularly Regulation #144), with respect to private placements of venture capital, limit the rate at which investors can recoup their investments. In short, the investors in these new firms are unable to obtain a fast payback. Entry into the public market poses extremely difficult problems also. For the new or small firm to go public, intensive preparations are necessary, involving high costs associated with registration of public issues. Furthermore, the entrepreneur bears a greater liability compared to the investor when entering the public market.

Tax Disadvantages

Although certain tax provisions have been designed to assist new entrants or small firms (such as Small Business Investment Companies (SBIC) and subchapter S of the IRS code), the new firm nevertheless encounters a variety of obstacles. For example, capital gains are treated less favorably than formerly, e.g., the increased holding periods and changed stock option provision. This is keenly felt by the small entrepreneur in need of investment capital. The new tax provisions reduce investor interest in investing in smaller, riskier firms. As investors themselves find such firms less interesting, the potential entrepreneur, having difficulty in selling his shares to the public, may be frequently induced to merge with older larger firms to avoid capital-gains taxes and obtain dividend payments.

Other provisions affecting the capital position of the new firm, compared to the older firm, are the loss carry-forward and carry-back rules. Existing firms can carry back losses, an advantage that is clearly impossible for new firms. Hence the older firm enjoys a financial advantage over new firms in introducing an innovation that does not bear immediate profits.

Regulatory Barriers

New firms may have greater difficulty in meeting environmental and health regulations than established firms, which are already structured to comply with such regulations. They may lack adequate managerial or technical skills to meet Government requirements. (Issue #4 proposes programs to deal with this problem.) Also, the total cost of compliance may be prohibitive for new or small firms, either discouraging their formation or inducing them to sell out or merge with larger firms.

Market Barriers

New entrepreneurs typically face greater market uncertainties. For example, established technologically advanced firms frequently benefit from substantial Government procurement. New firms with only a short track record may have little chance for Government contracts. Furthermore, the market power of existing firms bears heavily on the new small entrant. This power frequently results in their absorption through merger or acquisition or through product imitation by larger firms with well-organized marketing systems.

While solutions to these special problems are not always obvious and often run awry of other policy considerations, Congress should study measures to ease the problem of entry for new firms as well as to improve chances for survival against stronger, more established firms. Several alternative actions might be:

1. Early venture capital assistance (such as the National Research Development Corporation (NRDC) in Great Britain).
2. Industry-Government joint-venture arrangements.
3. Selective use of Government procurement to assist new technologically innovative firms. (Studies of the electronics industry have shown that Government procurement was an important factor in the early health of the industry.)
4. Stricter antitrust enforcement to strengthen the position of the new firm from the market domination of larger firms.
5. Consulting assistance to new firms in meeting regulatory requirements. (See issue #4 "Diffusion of Technology.")
6. More favorable tax treatment for new firms (e.g., higher carry-forward provision, changed depreciation, lower tax on capital gains).
7. Simplification of task of obtaining information about and using various Federal, State, and local incentives in form of cutoff rules in application procedures for small firms, and computer data-bank information sources on available aids.
8. Patent protection for small firms and inventors against violations and encroachments from larger firms, such as through use of a national patent board where violations can be reported and prosecuted where necessary.

ISSUE 4
Diffusion of Technology[8] Within the Private Sector

Should Congress consider comprehensive programs to enhance the diffusion of existing technologies and technical information within the private sector?

[8]Diffusion of technology from Government sources to the civilian sector is discussed in issue #1, and international transfers in issue #8.

Diffusion means the spreading of technology and technical information to new users. As opposed to generating new technologies, diffusion of existing technologies is usually a low-cost way to bring about greater economic benefits by: (1) raising productivity levels of industries by closing technology gaps, (2) encouraging more innovations by helping small- and medium-size firms compete with larger ones, and (3) promoting new uses of technology by means of transfers between different industries.

Many industries are characterized by a few, large technology leaders and many smaller producers. For the U.S. economy more than 95 percent of all manufacturing establishments employ less than 200 people.[9] Although there are other factors besides diffusion barriers which result in wide ranges of technology in terms of age and productivity being adopted by producers of similar products, there exist many opportunities where better diffusion can help close the gap between best-practice technology and average technology. A General Accounting Office (GAO) study of manufacturing productivity[10] suggests that wider diffusion of modern manufacturing technology can improve industrial productivity, especially among small batch-process manufacturers, which contribute 36 percent of manufacturing's share of the GNP. The study maintains that such productivity improvement can in turn increase the competitiveness of U.S. products, decrease the cost of Government purchases, and reduce inflationary pressure.

Technology gaps tend to stifle competition and reduce the incentive for large firms to innovate. By promoting diffusion of technology, the Government can help small- and medium-size firms compete more equally with larger ones, and also help foster more innovations. In the special cases of pollution control, health, and safety standards, the Government can help the diffusion of technologies for meeting these requirements and achieve wider compliance by helping small firms, which tend to lack the knowledge of regulatory requirements and the means to comply.[11]

[9]*U.S. Statistical Abstract, 1976* (Department of Commerce, Bureau of Census).

[10]GAO *Report to the Congress, Manufacturing Technology—A Changing Challenge to Improved Productivity,* LCD-75-436, Washington, D.C., June 1976.

[11]Charleswater Associates, Inc., *The Impact on Small Business Concerns of Government Regulations That Force Technological Change,* Report to SBA and NBS, September 1975.

The diffusion of technology used in one type of application to another can often result in new products, sometimes new industries. The use of sophisticated electronics in watches is perhaps an example. Thus wider diffusion of existing technologies not only increases opportunities to improve technology, but can also lead to more innovations. This is supported by the findings of the industry study in this report (see chapter III).

The funding of R&D to generate new technologies has often received much more attention than the diffusion of existing technologies to new users. Since diffusion is an important mechanism in raising average productivity levels of industries and in spreading the benefits of technological innovations to bigger segments of the economy, the problems of diffusion of technology in the private sector deserve Government attention.

The structure of the marketplace frequently works against the diffusion process. Many industries are dominated by a few, large technology leaders, which are obviously reluctant to help diffuse technology to their smaller, less efficient competitors. Such oligopolistic firms often use patent and patent-pooling practices to reinforce the diffusion barrier. By themselves, small firms often lack information and other resources to take advantage of more productive available technologies.

Given the lack of market forces to promote diffusion, there are few Government programs aimed at redressing the situation. The GAO study mentions some efforts by the Small Business Administration (SBA), National Technical Information Service (NTIS), and others, but maintains that such efforts are fragmented and very limited. In contrast, it points out that Western Europe and Japan have well-developed government-directed programs for overcoming barriers to diffusion. These include widespread regional productivity centers and various government-industry-university cooperative efforts.

To address the diffusion problem, a comprehensive policy might use a variety of instruments:

1. Establish a nationwide network of local centers,[12] that provide small firms with technical, informational, and consultative assist-

[12]A model of this kind of program, entitled State Technical Services, was enacted in the mid-1960's (22 U.S.C. 278). A residue of the program still exists in 23 States.

ance about the availability and use of technologies applicable to their needs through such means as:

- Technical agents that provide advice and assistance to firms on request and act as interface between firms and various sources of Government assistance such as NTIS, National Bureau of Standards (NBS), etc.;
- Seminars and workshops on technological problems/solutions for small firms in specific industries;
- Legal/administrative/technical assistance to meet Government regulations such as pollution, health, and requirements (e.g. Occupational Safety and Health Administration consultation program); and
- Financial assistance through loans, guarantees, or tax provisions for investments in regulatory compliance equipment and facilities (e.g. Environmental Protection Agency/Occupational Safety and Health Administration/Small Business Administration financial assistance for pollution control).

2. Support and encourage industry cooperative activities by small firms (within the limitations of antitrust legislation) through industry trade associations, professional associations, or marketing and purchasing cooperatives to:
   - Conduct adaptive R&D and demonstration projects of existing technologies for small-firm applications;
   - Construct jointly-operated production and pollution control facilities;
   - Purchase materials and services on a cooperative basis;
   - Articulate joint technical problems and needs; and
   - Promote group efforts of self-help.

3. Support for technology information/communications systems that serve both technology suppliers and users such as:
   - Government-operated systems such as NTIS; and
   - Private technology brokerage firms.

4. Require compulsory licensing to competitors when firms attain certain market-shares (see Japanese practice in chapter IV).

5. Support for programs where the Government purchases technology and resells it to multiple users (see Preproduction Order Support Program of Great Britain, in chapter IV).

ISSUE 5
Implementation of Environmental and Safety Regulations

Should Congress consider new means of implementing environmental and safety regulatory requirements which will encourage the development of innovative compliance technologies and safer products and materials?

Much of the debate concerning environmental regulation to date has focused on the need for new legislation and the stringency of regulatory requirements. Questions relating to implementation of the legislative mandates have been underemphasized. In particular, the role of technology vis-a-vis regulation has largely been ignored. The suggestion here is that increased policy consideration be given by Congress to issues concerning regulatory system design and implementation so as to encourage both the development of the new technologies necessary to achieve environmental goals and the development of safer products and materials.

There are at least two important aspects to the relationship between regulation and technological innovation. One concerns how regulation affects or is likely to affect innovation, and the other concerns the role of technological innovation in achieving regulatory goals. As to the first aspect, there has not been a great deal of systematic research about the effect of environmental regulation on U.S. technology[13] and the issue re-

[13]There have been several studies of the pharmaceutical industry, notably those of Peltzman (*Journal of Political Economy*, Vol. 81, September/October 1973), Wardell and Lasagna (*Regulation and Drug Development*, American Enterprise Institute, 1975), and Grabowski (*Drug Regulation and Innovation*, AEI, 1976). Other industries studies include automobiles (see Abernathy and chakravarthy, op. cit., p. 47) and an ongoing CPA study of the chemical industry.

mains controversial. From the evidence which does exist, one can say with certainty that it is impossible to make simple or general characterizations about the nature of the impact. At a minimum, it is necessary to distinguish between the direct effects on innovation in compliance efforts and the longer term, ancillary impacts on the general process of innovation. The effects in both instances are likely to vary significantly depending on the nature of the regulation and the regulated industry.

The effects of regulation can be positive or negative. For example, positive effects may often occur when regulatory requirements complement some existing market force (for example, in the case of fuel economy regulations on the auto industry—chapter III, p. 00) or where a new or ignored area of development can be exploited. Regulatory constraints, however, may hamper innovation by blocking certain new technical options or by decreasing the resources available for new product development. Of particular concern is the fact the regulation may hurt the competitive position of small firms.[14] As these effects can only be understood on a sector-specific basis there is a need for such analyses concerning the impact of regulatory programs as an imput to regulatory design (see issue #8 for further discusson of analysis needs).

Although the basic environmental requirements in the United States have been highly progressive (viewed internationally), mandatory standards have been the almost exclusive means used to achieve them. Some consideration has been given to the "technology-forcing" character of health-based regulatory standards,[15] but in general, the encouragement of new technologies has been absent as a conscious element of regulatory policy. This has not always been the case abroad, where several different approaches to regulatory design, which focus specifically on new technology, have been implemented.

[14]In addition to chapter III, see U.S. Department of Commerce, *The Effects of Pollution Abatement on International Trade—II, III, IV* (published yearly), which finds little or no effect on the U.S. trade position; I. Walter (ed.) *Studies in International Environmental Economics*, Wiley & Sons, New York, 1976, a series of essays; and Charleswater Associates, *The Impact on Small Business Concerns of Government Regulations That Force Technological Change*, Boston, 1975.

[15]See "Technology-Forcing and Federal Environmental Protection Standards," *Iowa L. Rev.*, February 1977.

The foreign experience is but one source from which new means of implementing regulations and facilitating regulatory compliance can be uncovered. A systematic effort to improve the design of regulations might include the following two components:

1. Evaluation, through such means as a task force, special commission, or research effort, of the means by which innovative compliance with regulatory needs can be achieved;[16] and
2. Application in appropriate regulatory contexts of demonstrations, experiments, or new policies designed to facilitate the achievement of regulatory goals through the encouragement of technological change.[17]

Either component would require congressional direction. Some of the particular regulatory alternatives, which might be either studied or implemented, are contained in the following list. It is not suggested that any of these alternatives be immediately adopted. Rather, they are offered as examples of possible new methods of regulating and serve to illustrate the need for a thoroughgoing reassessment of the means by which to achieve regulatory goals via technological innovation.

1. Expansion of direct Government support for in-firm technological development in crucial areas (e.g., pollution control in automobiles) leading to both process and product change.
2. Modification of pollution control tax incentives, i.e., accelerated depreciation and municipal bond financing, so as to favor process redesign and the development of new products and materials rather that add-

[16]The regulatory reform efforts of the Ford and Carter administrations are not what is envisioned here. These efforts have not concentrated on the utilization of technology but rather on an efficient regulatory process and the economic impacts of regulation.

[17]The ETIP Program in the Department of Commerce has as one of its components this purpose; however, it is a small effort.

on modifications associated with purchasing of pollution abatement equipment.[18]

3. Government financial support for major new technological advances when firms are unlikely to undertake them on their own either because such development would require large-scale efforts, would be long in coming to fruition, or their results non-appropriable (e.g. closed systems to contain toxic chemicals). This occurs in Germany and France as part of broader programs to encourage the development of new technologies for various social purposes.

4. Greater industry-specificity in standard setting (e.g. in the OSHA context) so as to minimize hardship when new technologies would be difficult to develop and to maximize health safety protection when the technological capacity is great.

5. Alternatives or supplements to standard setting, such as products liability or strict liability imposed on polluters, as in Japan.[19]

6. A formal antitrust exemption procedure to clarify the status of joint R&D relating to environmental control technology.

7. Special programs to assist small firms' compliance efforts (see issue #3).

8. Effluent taxes as a means of achieving water pollution abatement on a regional basis (these have apparently been successful in Europe, especially in Germany, and are alleged to provide continuing incentives for more efficient control technology).[20]

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[18]These provisions, Section 169 and 103 of the Internal Revenue Code, have been criticized as 1) ineffective, because the general investment tax credit is often more generous, 2) effectively available only to the large firms that can undertake municipal bond financing, and 3) penalizing radical improvements by their exclusion of "significant" (i.e., more than 5 percent) process change.

[19]The Japanese force polluters to compensate all victims of pollution via a system similar to workers' compensation. A bill to enact such a mechanism in the United States, H.R. 9616, was introduced in this session of Congress.

[20]Effluent taxes are widely endorsed by economists (see R. Solow, "The Economist's Approach to Pollution and Its Control," *Science*, Aug. 6, 1971). They are opposed by many others on a variety of grounds (see M. Weitzman, "Prices vs. Quantities," *Review of Economic Studies*, October 1974), especially where life-threatening hazards are involved.

ISSUE 6
Manpower Resources, the Labor Market, and Technology

Should Congress consider an integrated national manpower policy designed (a) to strengthen the contribution that qualified manpower can make to the innovation process and (b) to alleviate the disruptive impacts that rapid technological change can have on employment?

The interaction of labor and innovation is complex and frequently misunderstood. There is little disagreement over the key role that highly qualified manpower resources play in the innovation process. The existence of qualified technical personnel at all levels is critical to the environment for innovation. Most technologically advanced foreign countries place heavy emphasis on manpower policies as a key contribution to the capacity of industry and the research establishment to undertake technological change. The essence of these manpower policies is to prepare human resources for future needs of industries and the economy in general. As such, there is an element of long-term planning based on judgments about the nature of future needs.

While the importance of labor for technological change is clear, technological change itself has an impact on labor. As technological innovation raises demands for qualified personnel at one end of the spectrum, the effects of such innovation may cause a shift in demand for skills on the other end. Technological change in industries frequently leads to changes in the "skill-mix" which their production process requires. Certain worker skills may become obsolete and the result may be layoffs and serious dislocation.

The labor market issue therefore takes on a double dimension. Beyond the need for personnel in the technological innovation process, another basic issue is how to adapt a supply resource—manpower—to rapidly changing demand. Technological change in particular may lead to a shift in the demand curve for labor rather than a simple decline along the demand curve. This shift may cause a change in the demand for skills as opposed to the numbers of workers.

In general, the overall macroeconomic effect of technological innovation on employment levels is considered to be positive insofar as technological progress continually produces new products, processes, and services leading to new employment opportunities.[21] Technological innovation is a key element of a company's competitive position in domestic markets and of U.S. firms in general in international markets. Indeed, it can be argued that the failure of a company or sector to stay abreast of technological developments may over time lead to declines in employment as a result of the declining fortunes of the firm or sector. In this broader sense, therefore, labor has a genuine stake in the technological health of individual sectors and firms.

However, while the macro impact of innovation may be favorable for the employment picture over time, the micro effects of technological change may frequently result in serious labor dislocations. Manpower policy is therefore confronted with the problem of how to treat such disruptive impacts on the labor force that result from such changes at the level of the firm.

The United States today (as illustrated in program area IX in chapter III) has no conscious manpower policy specifically designed to strengthen the environment for technological innovation and to respond to the needs of workers in a technologically changing economy. In particular:

- There is no central body mandated to study and predict the impacts of technical change on the labor market.
- There exists no general labor adjustment assistance program (a) to assist workers financially to make the difficult transition from one job to another and (b) to offer workers retraining opportunities in skills that industry is currently in need of. The only current program deals with workers in industries "injured by excessive foreign imports."
- There is no longer term strategy, based on future projections, for educating middle- and higher-level technical personnel needed to sustain the process of technological innovation.[22]

Both short-term measures and longer term strategies are needed to meet these related objectives. Adaptive and continual training of manpower resources are required to provide labor with the mobility to adjust readily to changing skill requirements and to furnish the vital human inputs to the process of technological change.

The following outline suggests alternative measures for congressional consideration:

1. Manpower Forecasting and Planning—to prepare basis for labor adjustment assistance and long-term technical education strategy:
   - — Early-warning systems in various sectors to predict areas of foreseeable labor shortages and surpluses; and
   - — Mechanisms for translating the above data into policy planning options for educational strategy and labor adjustment assistance.

2. Labor Adjustment Assistance—short- and medium-term measures to assist displaced workers:
   - — Financial assistance to aid worker transition from job to job;
   - — Adequate financial aids to workers to undertake retraining for new jobs;
   - — Incentives to firms to retain and retrain their own personnel for new positions (as in Japan) or payroll taxes on employers to finance worker retraining (as conducted in France);
   - — University-industry cooperation for retraining of higher level personnel in industry for new responsibilities;
   - — Publicly financed continuing education centers for displaced workers according to sector or industry;
   - — Improved employment information and placement services according to sector or industry to assist in rapid relocation of workers.

[21]Lowell Gallaway, "Labor Mobility, Resource Allocation, and Structural Unemployment," *American Economic Review*, LM No. 4 (September 1963); Otto Eckstein, "Aggregate Demand and the Current Unemployment Problem," in *Unemployment and the American Economy*, ed., A.M. Ross (New York: John Wiley & Sons, 1964).

[22]It should be noted that there is also nothing in the United States approaching the European movement toward codetermination that would guarantee labor a voice in management decisions concerning technology.

3. Long-Term Technical Education Strategy—to improve the environment for technological innovation:

- Establishment of training institution network to prepare middle-level technical personnel;
- Raising the professional stature and increasing financial rewards for teaching personnel in technical institutes;
- Mandatory continuing education in certain key technical fields (e.g. where licenses required);
- University-trade school-industry cooperation for upgrading and updating scientific and technical personnel; and
- Incentives to industry for in-house traineeships for qualified personnel (as practiced in Germany for example).

ISSUE 7

International Commerce and Domestic Innovation

Should Congress consider a comprehensive program to strengthen the U.S. position in international trade by enhancing the technological competitiveness of U.S. industries adversely affected by international commerce, and assisting labor and business to adjust structurally when dislocations occur?

International commerce (trade and technology transfer) has important implications for domestic innovation. First, technological innovation is a major determinant of competitiveness in international trade.[23] Competition with foreign producers in international markets as well as in the United States increases the need for U.S. producers to innovate. Second, access to foreign markets provides an extra stimulus to U.S. innovations by increasing the demand for U.S. goods and technology. Third, proceeds from foreign sales of U.S. corporations help finance their R&D. It is estimated that the foreign sales of U.S. corporations (after consolidating their exports from the United States and overseas sales of their foreign subsidiaries) accounted for almost one-third of their total sales in 1976.[24] Fourth, technology transfer from abroad has stimulated or complemented many U.S. innovations. To cite a few examples, continuous casting and the basic oxygen furnace in steelmaking, the jet engine, float glass manufacturing, and penicillin were all first introduced abroad and then brought to the United States.

While many benefits for the U.S. economy and for domestic innovation derive from internation commerce, there are clearly problems for some U.S. industries also. Competition with foreign producers, whether here or abroad, is a dynamic process that creates a changing mix of opportunities and problems for U.S. industries as comparative technological advantages shift over time. Coupled with other changing international conditions, this has caused domestic job losses in some sectors, or is threatening to do so, through rising imports or declining exports.

Consumer electronics, steel, textiles, and shoes are examples of industries severely undercut by imports and where domestic jobs have been lost by the closing of plants in the United States. In these sectors, there is strong labor and business sentiment in favor of restricting imports. In other manufacturing sectors, labor groups have voiced forceful complaints against the export of jobs by U.S. companies transferring technology and making direct investments in foreign countries. Although some have argued that these actions by U.S. businesses are defensive in nature and in response to changing international conditions and some have even argued that there are net gains in U.S. jobs as a result of U.S. direct investments overseas,[25] there are undeniable job losses for specific workers.

Although in the modern world of increasingly interdependent economies international commerce is essential to national welfare, it results in costs as well as benefits. Because of these costs, there is mounting pressure on the U.S. Government to institute protectionist measures. How-

[23]See, for example, Raymond Vernon (ed.), *The Technology Factor in International Trade* (National Bureau of Economic Research, New York, 1970).

[24]Based on sample of 295 U.S. companies with a combined total sales of $588 billion, as reported in "Foreign Sales Special Report," *Standard and Poor's Industry Surveys*, July 28, 1977.

[25]See, for example, several studies summarized in Robert Hawkins, *Job Displacement and the Multination Firm—A Methodological Review*, Center for Multinational Studies, Occasional Paper No. 3, Washington, D.C., June 1972.

ever, protectionist measures alone are unsatisfactory and dangerous without accompanying actions to remedy basic structural weaknesses. Protectionist measures tend to generate inflationary pressures domestically and invite international retaliation against U.S. exports, both of which will cause more job losses. They merely alleviate symptoms and reinforce long-term rigidities in industrial structures, while denying U.S. consumers cheaper or better products. While short-term protectionist measures may be necessary in some cases, they should be accompanied by a comprehensive package of technological/structural adjustment programs that can soften the dislocations caused by declining industries, help revive their competitiveness, or assist in their transformation.

Although there are programs in existence for labor and business adjustment administered by the Departments of Commerce and Labor and the International Trade Commission, they are inadequate and fragmented for this purpose. An integrated policy towards technological/structural adjustment might include the following components:

1. An early-warning system based perhaps on the kind of sector-specific microanalysis (see issue #6) that would yield forewarnings about declining industries and their problems and thus avoid crisis-triggered reactions (e.g. the recent case of steel). This system should be part of a policy-formulating unit that will coordinate relief and adjustment assistance decisionmaking.
2. A comprehensive labor adjustment program that can help labor adjust, retrain, or relocate (see issue #4).
3. A comprehensive business adjustment program which may include:
   - Short-term protectionist support under special circumstances (e.g., for vital or infant industries);
   - Capital support for modernization and restructuring (e.g., R&D funds, exemption from antitrust of joint R&D by industry);
   - Regulatory support (relaxation or exemption of regulatory measures that impact on industry, e.g., in a recent case, water pollution standards were relaxed for parts of the steel industry); and
   - Export support (e.g., use of Export Import Bank (EXIM) bank facilities or tax provisions similar to the Domestic International Sales Corporation (DISC) to promote industry exports).
4. An R&D support system that enhances the technological competitiveness of U.S. industries by supporting:
   - Technological development based on assessments of U.S. comparative advantages (see issue #8, sector-specific microanalysis);
   - Technological development that can raise industrial productivity across many sectors (see issue #1);
   - Technological development that can lead to new industries or markets (both domestic and export); and
   - Adaptation and improvement of advanced foreign technologies by domestic industries.
5. Selective use of incentives/disincentives to inflows of technology through the channels of trade, contractual arrangements, and direct investment (as Japan did in the 1950's and 1960's through the Ministry of International Trade and Industry).
6. Selective removal of barriers to technology transfer from abroad, e.g., bias against foreign testing data under Food and Drug Administration regulations on introduction of new drugs (see program area XI, chapter III, for other tariff and nontariff barriers).

ISSUE 8

Support for Sector-Specific Microanalysis

Should Congress consider support for systematic and ongoing analyses of the social, economic, and technological issues pertaining to individual industrial sectors as an input to public decisionmaking?

The overall purpose of this report has been to understand the relationship between technological innovation and Government action. One of the major premises underlying its execution is that this relationship can best be understood on a sector-specific basis. This was a major reason for undertaking a series of industry studies (see chapter III). As the work progressed, however, it became increasingly apparent that there are serious deficiencies in the knowledge base:

- On the industry side, there were often major gaps in the literature concerning the technology-related problems of the sector, such as obsolescence, capital needs, position in international trade, etc.
- On the Government program side there existed an even greater lack of evidence about the effects of various programs and serious deficiencies in the knowledge base upon which to make regulatory decisions.

These deficiencies arise in part from the fact that there is no sector-specific microanalytical capability of significant size in Government today. For example, the Domestic and International Business Administration, part of the Department of Commerce, has concentrated more on macroeconomic data than on sector studies. The National Science Foundation has funded some studies and the National Bureau of Standards also has some capability along these lines, but each is a very small effort. Regulatory agencies also sometime fund such studies in response to a crisis. While these studies may fulfill an immediate regulatory need, they are generally not readily applicable to other governmental needs. Although existing studies performed in firms might provide some useful information, they are often proprietary and not designed to suit governmental purposes.

Accordingly, there is a need for an expanded, Government-supported capability. Most Government actions which significantly affect the technology of an industry must be taken on a sector-specific basis. For example, air and water pollution control standards are, almost without exception, different according to the sector affected. This is a natural consequence of the difference in hazards present and the different technological and economic capabilities of the relevant sectors. Energy conservation regulations are another example of a Government function that cannot proceed without sector-specific disaggregation. Concerns relating to export and import controls, productivity, and employment also require detailed microanalysis for Government decisionmaking.

One example of a study that might be undertaken concerns the steel industry, whose health is currently a subject of major national controversy because of its position in international trade and its ability to comply with environmental regulations. Good thorough studies of the technological position of the U.S. steel industry will be needed in order to develop and implement new policies toward it. Another example might focus on the effect of international trade and foreign direct investment by U.S. multinationals on domestic employment. Because most existing studies only examine net aggregate employment impacts and provide no information as to where the employment gains and losses in fact occur, policies to provide structural adjustment are severely hampered.

Other research needs might include analysis of the capital investment needs in specific sectors, the impact of regulation on technology in selected industries, or the effectiveness of existing Government programs on a sector-specific basis.

There are several institutional alternatives possible to support such analysis including:

1. Government financial support for sector analyses performed in universities or research institutes;
2. Support for industry-performed analyses; and
3. Performance of the analyses in one or more Government agencies.

Irrespective of the institutional arrangement, the analysis could be oriented either toward (1) broad policy areas such as control of international trade, but with particular reference to individual sectors or (2) specific sectors, such as steel, for use in a variety of policy contexts. In either event, the analysis would be useful to the formulation of public policy in regulation, planning, establishing research priorities, etc; and could aid private decisionmaking as well by providing a data base and new syntheses of existing information.

ISSUE 9

Support for Hazard Analysis

Should Congress consider supporting additional national capability for anticipating significant hazards arising from new and existing technologies?

Recognition and control of significant hazards before they create damage is obviously a desirable goal. Several existing regulatory systems attempt to fulfill this purpose with regard to new chemical products or uses (e.g. pharmaceutical, pesticide, and toxic substance regulation—see policy area II for this listing). In addition, assessments that may have hazard identification and analysis as a component are performed by various agencies (e.g., the environmental impact statement process required for major Federal actions, OTA studies, etc.—see program area I, chapter III).

While each individual program has its own virtues and drawbacks, the overall effort may lack suffient purpose, coordination, and capability to respond to the national need for hazard recognition and prevention, especially with regard to hazards already in the marketplace or environment. There are several reasons for this.

First, is the existing programs coordination.[26] For example, although the dangers of a toxic substance in the workplace may be recognized, its control as a hazard in the atmosphere or in a consumer product is often not coordinated with the workplace regulatory effort. This may result in transfer of the hazard from one location to another (for example by ventilation from a factory into the atmosphere) rather than effective control.

Second, hazard analysis is not contained within the mission of many agencies. For example, the National Aeronautics and Space Administration and the Department of Defense had the capability but not the responsibility to be concerned about satellite radioactivity before the recent Canadian incident involving the crash of a Soviet satellite. Moreover, the hazard analysis function that does exist is typically only incidental to the larger agency mission. For example, EPA's pesticide division attempts to prescribe labels, register pesticides, prescribe standards for licensing applicators, as well as to prevent "unreasonable adverse effects" on the environment.

Third, hazard analysis is a relatively new discipline and has so far achieved little recognition or support. Consequently, its analytical techniques are as yet underdeveloped.

For all these reasons, hazards typically go unrecognized until a crisis develops. The record of the environmental/safety movement is replete with examples in this regard: vinyl chloride, recombinant DNA, and most recently, radioactive debris from a Soviet satellite.

Several alternative policies may be undertaken to expand and improve the existing hazard analysis capability, including:

1. A central hazard identification/analysis mission and capability located in a Government agency, for example OTA or EPA. This agency could either conduct or coordinate hazard analysis efforts in Government.
2. Government financial support for hazard analysis performed elsewhere (for example, through NSF).
3. Government support for training and research to develop a hazard analysis capability, for example, through curriculum development, support for students, publications, etc.
4. Hazard identification and analysis in firms—although this is occuring already to some extent as a result of regulatory and legal (e.g. products liability) requirements, new, more formal requirements could be imposed.
5. Education of workers and consumers in hazard identification.
6. Systematic and ongoing monitoring of environmental and health research in the United States and abroad to keep abreast of new developments.
7. Adequate followup analyses or procedures to ensure that hazards identified are controlled to the extend feasible and to monitor the analysis capability.

[26]The recent voluntary cooperative effort in the toxics area by OSHA, EPA, CPSC, and FDA is an encouraging initial step at meeting this problem.

Whatever the mechanism, its existence may be as important as its form. Although hazard identification/analysis can be a systematic, scientific undertaking, it is also undeniable that it may involve a good deal of serendipity. Therefore, a consciousness about the problem and a mission to be concerned with it may be as important as the development of new analytical techniques.

ISSUE 10

Affecting the Demand for New Technologies.

Should Congress consider increased use of programs of policies that focus on the demand for new technologies rather than on supply?

Most Federal programs intended to affect technological innovation have historically been concerned with the supply of new technologies. Accordingly, they have attempted to increase this supply by, for example, reducing the cost of development, undertaking research in publicly supported laboratories, increasing the rewards for innovation, etc. (See program areas IV through VIII in chapter III.) This policy emphasis has resulted in part from a widely held, but overly simple, view of the innovation process, which sees R&D as the overridingly important aspect. In contrast, recent research emphasizes the complex interconnectedness of various stages in the innovation process and recognizes that market demands are often a more important motivator of innovation than technical discoveries.

Experience suggests that policies which work through influences on demand may often be more effective than those which concentrate on increasing supply. One way of influencing demand is by Government procurement. Evidence presented earlier in this report shows that an assured Government market for new products can be an effective stimulus to innovation. This conclusion is also strongly supported by the foreign experience. Another way of influencing demand is to impose a Government requirement. Environmental regulation, for example, had fostered innovation by creating a demand for safer, nonpolluting technologies. Both of these examples show programs that create new or expanded markets.

Most of the factors that mold consumer demand for new technologies arise from the private market. Advertising, marketing techniques, and various other kinds of market information play a predominant role in this regard. Although advertising regulation has long existed, it has, until recently, been limited in scope; however, new Government initiatives are likely to influence consumer demand more directly. For example, recent developments in counter, corrective, and comparative advertising attempt to ensure a balance of viewpoints in the commercial marketplace.

Other existing programs also affect demand. For example, product safety regulation may effectively shift consumer demand toward a preference for safe technologies embodied in consumer products. Although such shifts may in fact occur, they are largely unintended from the viewpoint of the regulators, whose major interest is to remove unsafe products from the market, and only incidentally to promote the development of new, safe technologies. (These and other policies are identified in program area XII.)

The potential importance of policies intended to affect demand may be illustrated in the development of energy conservation technology. Decreases in demand (through conservation) and shifts in the nature of demand (through a preference for energy-efficient or nonconsumption alternatives) are both required for conservation to be successful. In order to achieve these two goals, major changes may be required in existing products, production processes, and individual lifestyles. If this is indeed the case, Government action may be necessary to (1) inform consumers fully about the means and benefits of energy conservation, (2) persuade them to adopt different consumption patterns, and (3) counteract or control existing advertising practices inimical to energy conservation.[27] Moreover, the Government could vastly increase the demand for energy-efficient technologies by subsidizing their users, for example, through a tax credit for solar heating or low-interest home insulation loans. Similarly, Government purchase of such products could speed their development and commercialization.

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[27]As an example of this third option, France has recently instituted a major program to prohibit any advertising that encourages energy consumption.

Energy conservation is but one example of the areas in which Government can affect technological change through influences on demand rather than by encouraging supply. It is used as an example not to advocate any specific program, but rather to illustrate how the Government can work through demand-side policies in a variety of ways.

The existing imbalance between supply and demand-based policies in the overall Government approach toward technological innovation strongly suggests that consideration should be given to increased use of programs focusing on demand. Such programs might include the following components:

1. Greater emphasis on mechanisms that create new or expanded markets for certain types of technology, for example:

—procurement,
—user subsidy,
—products liability, and
—regulation.

2. Greater emphasis on mechanisms that directly influence the nature of consumer demand, for example:

—counteradvertising,
—consumer information provision, and
—education.

Glossary of Acronyms

AID —Agency for International Development
ANVAR —National Agency for the Valorization of Research (French)
ASRA —Applied Science and Research Applications, a directorate of the National Science Foundation
CAB —Civil Aeronautice Board
CEQ —Council on Environmental Quality
CPSC —Consumer Product Safety Commission
CWPS —Council on Wage and price Stability
DISC —Domestic International Sales Corporation
DOC —Department of Commerce
DOD —Department of Defense
DOE —Department of Energy
DOJ —Department of Justice
DOL —Department of Labor
DOT —Department of Transportation
EIS —Environmental impact statement (also econmic impact statement)
EPA —Environmental Protection Agency
ERISA —Employee Retirement Income Security Act
ETIP —Experimental Technology Incentives Program
EXIM —Export Import Bank
FCC —Federal Communications Commission
FCIA —Foreign Export Credit Insurance Association
FDA —Food and Drug Administration
FTC —Federal Trade Commission
GAO —General Accounting Office
GATT —General Agreement on Tariffs and Trade
HEW —Department of Health, Education, and Welfare
HUD —Department of Housing and Urban Development
IIS —Inflationary impact statement
ITC —International Trade Commission
IRS —Internal Revenue Service
MFN —Most Favored Nation
NAE —National Academy of Engineering
NAS —National Academy of Sciences
NASA —National Aeronautics and Space Administration
NBS —National Bureau of Standards
NHTSA —National Highway Traffic Safety Administration
NIH —National Institutes of Health
NLRA —National Labor Relations Act
NRC —Nuclear Regulatory Commission
NRDC —National Research Development Corporation (British)
NSF —National Science Foundation
NTIS —National Technical Information Service
OPIC —Overseas Private Investment Corporation
OSHA —Occupational Safety and Health Administration
OSTP —Office of Science and Technology Policy
OTA —Office of Technology Assessment
PEFCO —Private Export Funding Corporation
SBA —Small Business Administration
SEC —Securities and Exchange Commission
STR —Special Trade Representative
TOSCA —Toxic Substances Control Act
TUP —Technology Utilization Program
USDA —U.S. Department of Agriculture

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